Queensland University of Technology

CRITICAL SUCCESS FACTORS FOR THE IMPLEMENTATION OF A KNOWLEDGE MANAGEMENT SYSTEM IN A KNOWLEDGE-BASED ENGINEERING FIRM

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ABSTRACT

Knowledge Management Systems (KMS) are IT-based systems that facilitate and sustain the creation, sharing, application, storage, and dissemination of knowledge. This thesis identifies the critical success factors (CSFs) for implementing KMS in a knowledge-based engineering firm.

This research is funded by CVEng (real name withheld for confidentiality purposes), which is an engineering consulting firm seeking to innovate its operations by implementing a KMS. The objective of the research is to determine the factors that would ensure the successful implementation of a KMS in CVEng.

Following a review of existing knowledge literature a list of critical success factors (CSFs) for KMS implementation is proposed within a research conceptual model. The CSFs include management support, culture, the establishment of a KM infrastructure, employee motivation and buy-in, the availability of resources, performance metrics, and KM strategy.

The proposed research model is then validated using the Delphi method with a panel of experts assembled from senior members of the Australian construction industry. Qualitative data was gathered by means of questionnaires. Quantitative data analysis was made possible by allocating numerical ranks to the CSFs. Convergence of expert opinion was measured by using Kendall's coefficient of convergence *W*. The Delphi study validates the CSFs in the research model and added one more CSF not commonly cited in the existing literature.

A case study of CVEng is then undertaken to determine CVEng's organisational readiness to implement a KMS. A series of interviews were conducted with directors and senior managers of the firm to establish CVEng's organisational profile, strengths and weaknesses. These are then benchmarked against world's best practices as identified in the knowledge literature. The results of this study indicate that certain changes must be made within the organisation for the KMS to be successfully implemented. The changes encompass various aspects of the

organisation, ranging from organisational culture, financial support, leadership, and effective communication.

This research is expected to generate new knowledge relating to KMS in the Australian construction industry. The findings of this research apply most pertinently to CVEng who sponsor this research, but other firms may find the findings relevant to their circumstances. Notwithstanding, the list of CSFs for KMS implementation is expected to be applicable to a wide range of stakeholders within the construction industry.

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LIST OF ABBREVIATIONS

CAD	Computer Aided Design
CSF	Critical Success Factor
IMP	Innovation Management Program
IS	Information System
IT	Information Technology
KBF	Knowledge Based Firm
KM	Knowledge Management
KMS	Knowledge Management System
KPI	Key Performance Indicator
SME	Small to Medium Enterprises
QA	Quality Assurance
QUT	Queensland University of Technology

STATEMENT OF ORIGINAL AUTHORSHIP

The work contained in this thesis has not been previously submitted to meet the requirements for an award at this or any other higher education institutions. The work contained within is solely the work of the undersigned except where clear reference is made within the text of the thesis to a third party.

Signature: QUT Verified Signature

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1. INTRODUCTION

Innovation has been singled out as the primary way in which firms can improve their market position and maintain a sustainable competitive advantage. Recent IT developments in communications and economic trends have propelled knowledge to become the primary resource in many organisations in the world. Firms whose primary resource is knowledge are collectively termed knowledge-based firms. It then follows that it is in knowledge that knowledge-based firms can best innovate, as it will yield the most tangible and immediate benefits. The act of strategically managing knowledge such that it can be leveraged to the firm's competitive advantage is termed knowledge management (KM).

Despite numerous KM projects in organisations around the world, success has been varied. Furthermore, the many factors that influence the success of any organisational change initiatives are many, and their interrelationships are highly complex. Understanding the crucial factors that lead to a successful KM project is therefore prudent for organisational strategic planning. One concept that was made popular by JF Rockart is the critical success factor concept, whereby a successful venture is ensured if the few critical success factors are satisfactorily achieved. Identifying critical success factors will facilitate focused monitoring on a few key areas of the business, from which Key Performance Indicators (KPIs) may be established, benchmarked, and monitored.

There have been many critical success factor studies conducted by academics and KM practitioners worldwide, but studies specific to the engineering and constructions are scarce in number. Further, most studies are theoretical and too general to be relevant to an aspiring innovating firm. This research is aimed at closing this knowledge gap, with a specific emphasis on the needs of a multi-national engineering consulting firm, who sponsor and fund this study.

This research is expected to generate new knowledge in the field of knowledge management in knowledge-based engineering firms. It also aims to provide practical recommendations for the sponsor firm to support knowledge management initiatives in their operations.

1.1 BACKGROUND OF RESEARCH

This research was commissioned and funded by an Australian engineering consulting firm, which shall remain anonymous for confidentiality purposes. For convenience in subsequent discussions, this firm shall be referred to as "CVEng", a fictitious name given by the author. The author is a full-time employee of CVEng.

As part of their overall innovation venture, CVEng are looking at developing and implementing a knowledge management system (KMS) in order to improve the efficiency of project delivery and increase its competitiveness in the current market conditions. As a knowledge-based firm (KBF), CVEng rely heavily on the creation and transfer of knowledge to deliver successful projects, all of which are unique in nature. Yet, CVEng currently does not have any formal organisational processes in place that tap into and leverage the inherent knowledge exchange and creation to the benefit of the whole firm. Many of CVEng's competitors have developed extensive KM initiatives such as a KMS in order to remain competitive in the global and Australian construction markets. The reality and fierceness of the competition was experienced by the market in the recent global economic downturn of 2008-2010, during which the number and scale of construction projects in the private sector dwindled, and engineering consultancy fees dropped to record lows. There is also a sense of urgency to capture the knowledge residing in the minds of the senior executives and managers, many of whom were instrumental in the founding and rapid growth of the company, prior to their imminent retirement. All these factors have prompted CVEng's management to sponsor a number of post-graduate research studies under the umbrella of the Innovation Management Programme (IMP). The IMP addresses many different facets of the business such as risk management, leadership, knowledge management, and business development. This research focuses on the implementation of a KMS in CVEng.

1.2 RESEARCH PROBLEM

The objective of this research is to investigate the measures by which a successful implementation of a KMS can be achieved in CVEng. The primary research question is:

HOW DO WE ENSURE THE SUCCESS OF A KMS IMPLEMENTATION IN A KNOWLEDGE-BASED ENGINEERING FIRM?

The critical success factor method has been pre-selected as the ideal method to address the above question. The main research questions can then be translated as:

WHAT ARE THE CRITICAL SUCCESS FACTORS FOR THE IMPLEMENTATION OF A KMS IN A KNOWLEDGE-BASED ENGINEERING FIRM?

Once the critical success factors have been identified, the research then aims to investigate the cultural, organizational, financial, and management conditions of CVEng in order to establish CVEng's readiness to implement a KMS. This study also aims to identify gaps in CVEng's organizational capabilities and to make specific recommendations to address this gap in order to ensure a successful KMS implementation.

1.3 DESIGN OF THE PROPOSED RESEARCH

This research is a combination of theoretical and practical research. The research methodology consists of four stages, as illustrated in Figure 1.

1.3.1. STAGE 1: LITERATURE REVIEW

The literature review is arranged in two main parts. The first part aims to define innovation, knowledge-based firms, and their links with knowledge management and knowledge management systems. The review also introduces the accepted knowledge management typology, which serves as the foundation for subsequent discussions. The second part identifies the many critical success factors for knowledge management systems found in the literature and synthesises them into a set of factors that are relevant to knowledge-based engineering firms.

The findings from the literature review are then used to develop a research model that consists of hypothesised correlations between critical success factors and the successful implementation of a knowledge management system, the model variables being the critical success factors. This model is tested and validated in Stage 2.

1.3.2. STAGE 2: VALIDATION OF CRITICAL SUCCESS FACTORS MODEL

The next stage of research involves the testing and validation of the critical success factors model developed through the literature review. The model variables are validated by means of a Delphi study. The Delphi method has been chosen due to its emphasis on a focused group of experts in a specific area of interest. In order to validate the critical success factors, the Delphi panellists must have an extensive managerial experience in their field of practice. In this research, the chosen Delphi panellists were senior members of organisation in the Australian engineering and construction industry, which includes architects, engineers, contractors, and project managers.

The Delphi method also has the ability to retrieve a convergent set of data. Unlike the standard questionnaire, the Delphi method goes one step further by follow-up questionnaires based on the results of the previous round of questionnaire. This way good data convergence is usually achieved.

Data collected in the Delphi study is analysed by using statistical and correlations analysis. The results are then used to refine the critical success factors model for knowledge-based engineering firms. The outcome of this stage of research is therefore the refined critical success factors model, which would be applicable for knowledge-based engineering firms in developed markets similar to Australia around the world.

All data collection for this research was conducted in strict conformance to QUT's Ethics policies. The Delphi participants were requested to read and sign a research participation consent form prior to commencing data collection. The QUT Ethics application form for this research and a template of the participation consent form can be found in Appendix A.

1.3.3. STAGE 3: KM GAP ANALYSIS AT CVENG AND RECOMMENDATIONS

Following the validation of the critical success factors model, a KM gap analysis is performed in the context of CVEng. Specifically, the gap analysis examines the current cultural, organisational, financial, and management conditions of CVEng against the validated success factors model. The objective of this research component is to make recommendations relating to CVEng's organizational readiness to successfully implement a KMS.

Data collection for this research component was conducted internally within CVEng. Senior managers were selected as representatives of the firm, as they have an innate knowledge of the firm's vision, strategic direction, and financial status. Several key senior managers were selected for in-depth interviews, which were conducted on a one-to-one basis.

1.3.4. STAGE 4: RESULTS AND CONCLUSIONS

The final stage of research presents a summary of CVEng's cultural, financial, organisational status based on the results from Stage 3 of research. The summary highlights the strengths and weaknesses of CVEng from a KMS implementation perspective. From this, specific recommendations are made addressing CVEng's organisational readiness for the successful implementation of a KMS.

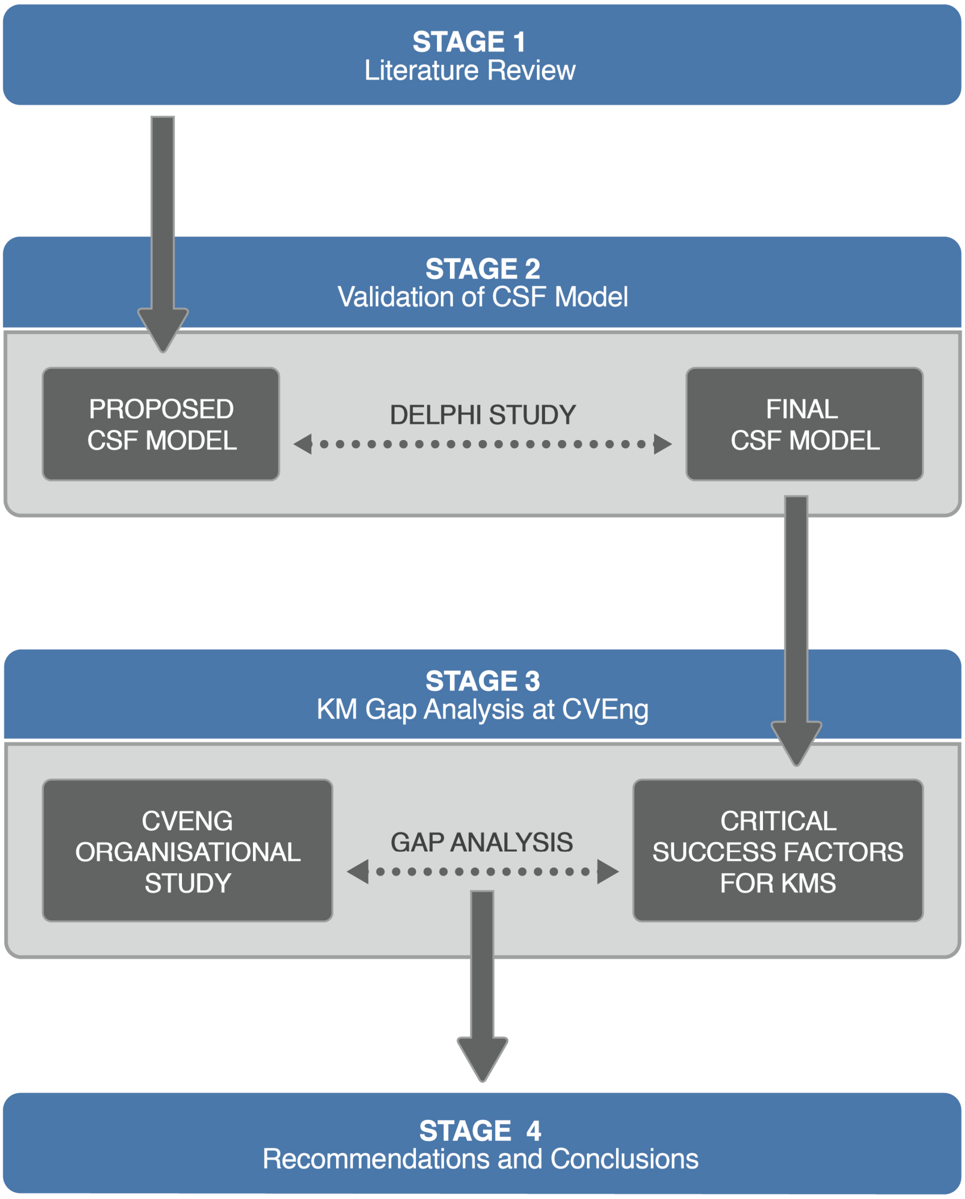

Figure 1 – Research methodology

2. LITERATURE REVIEW

This chapter reviews the literature on the following topics: innovation, knowledge-based firms, and what constitutes knowledge. The interrelationships between these concepts will then be explored, leading to a discussion on knowledge management systems and the concept of critical success factors in relation to the implementation of such systems. The final section develops the conceptual framework and research model for this study.

2.1 INNOVATION

The innovation literature defines innovation as a process that results in the introduction of a new or improved product, service, or process to the market (Oke, 2004; Olsen, Lee, & Hodgkinson, 2006). Innovation is a promoter of economic growth and is the key to firms gaining competitive advantage in the market (Chow, Goodman, Rooney, & Wyble, 2007). However, measuring innovation and its impacts on growth proves problematic, as is not the only factor affecting growth (Chow et al., 2007; Oke, 2007). Despite this, there have been numerous studies and statistics that demonstrate the positive correlation between innovation and growth (see, for instance Linder, 2006).

A common typology distinguishes two different types of innovation, namely product innovation and process innovation (Egbu & Botterill, 2001; Olsen et al., 2006). Product innovation refers to the introduction of a new or improved product to the market. Process innovation denotes an improvement in production methods that results in increased productivity growth. Hodgkinson (1998) asserted that product innovation is easier to imitate than process innovation, as the product is made available in the market as opposed to processes which are usually protected by trade secrets. Innovation can also be incremental or radical. Radical innovation is commonly found in R&D, and is usually a response to some external pressure from the environment, resulting in sudden breakthroughs (Egbu & Botterill, 2001). In contrast, incremental innovation occurs more gradually and builds on existing products and technology to develop improved products and processes. Innovations in pharmacy and medicine are usually incremental in nature.

There are two schools of innovation economics, namely the Neoclassical and Schumpeterian schools, named after its pioneer, the philosopher turned economist Joseph Schumpeter (Olsen et al., 2006).

The Neoclassical school revolves around the concept of economic equilibrium, with rational, well-defined economic behaviour based on cost-based analyses. In this view, when economic equilibrium is achieved, or when investments in innovation do not yield the expected ROI, the innovating firm would reduce or even cease innovative efforts, favouring static growth. Arrow (1962) popularised the concept of “learning by doing” in economic growth. He argued that the knowledge base of a firm would by default expand as the firm undertakes new activities. Arrow’s concept allows for continuous growth and paved the way for subsequent innovation theories involving knowledge and intellectual capital as important inputs for production.

Joseph Schumpeter is credited as the first economist who established the relevance of innovation in economics (Olsen et al., 2006). Schumpeter (1939) argued for a more dynamic view to economic growth, with innovation at its core. He also introduced the concept of “creative destruction”, whereby firms with innovative, superior products or processes can break down the barriers that prevent new firms from entering an established market. Schumpeter’s theories gave rise to evolutionary economics, aptly named after its close ties with Darwinian evolutionary theory. Nelson and Winter (1982), who pioneered evolutionary economics, argued that in order for organisations to survive the market competition, they need to “evolve” or “mutate” by engaging in innovative activity. Other firms will typically imitate a firm’s success in innovation as they “adapt” to changing market conditions. For instance, when Chemical first introduced networked Automated Teller Machines (ATM) in the 1970s, it gave them business advantage over their competitors as their customers can conduct faster transactions without the need to queue for a teller. Several years later, the ATM became a standard requirement for all consumeroriented banks, negating the advantage initially possessed by Chemical. Failure to engage in innovative activity or to adapt will result in the loss of market share and consequent loss in profits, leading to potentially exit from the market. In an increasingly competitive global market where market conditions fluctuate frequently, the evolutionary view of economics calls firms to engage in continuous improvement and innovation (Johannessen, Olsen, & Olaisen, 1999) to maintain and improve their market share.

2.2 KNOWLEDGE BASED FIRMS

In recent decades, globalisation and the exponential growth in information technology (IT) have driven the global economy toward a knowledge-based economy, which are “directly based on the production, distribution and use of knowledge and information” (OECD, 1996). Concurrently, this economic shift has given rise to the theory of the knowledge-based firm (KBF), which views firms as organisations in which human and intellectual capitals are the main resources on which the firm operates (Grant, 1997). KBFs have the following characteristics (Alvesson, 2004):

- Emphasis on non-standard problem solving
- The majority of employees have high educational level
- Dependency on key employees
- High level of creativity
- Human capital is the most important resource

The employees of KBFs are collectively known as “knowledge workers”, a term that was first coined by Peter Drucker in 1959 (Wallin & Stipic, 2007). As the term implies, knowledge workers primarily work with information (Wallin & Stipic, 2007)) and are highly educated professionals (Sveiby, 1997). They deal with complex problems which require a high level of knowledge as the main production tool to solve (Alvesson, 2004; Wallin & Stipic, 2007). Examples of knowledge workers include engineers, accountants, lawyers, scientists, and consultants.

CVEng is an Australian professional engineering consulting firm that specialises in building structures, civil works, and temporary construction works. With approximately 300 employees, and offices in London, Dubai, and most Australian capital cities, CVEng is capable of delivering engineering projects in development hotspots around the world. At its core business, CVEng employs a team of engineers, drafters, and project managers to deliver projects and generate revenues. CVEng also employs teams of accountants, lawyers, IT support, human resource and marketing managers to support its core business. While it is desirable to consider all operational divisions of CVEng, the scope of this thesis is restricted to those core divisions, namely engineering, drafting, and project management, as it is within these disciplines that innovation will yield the most direct and tangible impact to the business. For the purposes of discussions, therefore, subsequent references to CVEng only relate to the three core divisions as mentioned previously.

CVEng exhibits similar characteristics to a knowledge based firm as proposed by Alvesson (2004). For example, all CVEng engineers and project managers are highly educated professionals with tertiary qualifications. Further, engineering projects are essentially problem-solving exercises at a large scale. Differing architectures, ground conditions, and building occupancy types mean that no engineering projects are the same. Each project has its unique challenges and problems, which require the engineers to apply their expertise and problem-solving skills in order to ensure a successful project outcome. To do this, the engineers mobilise the knowledge they accumulate by training and experience, and re-apply it in new and innovative ways. In this way engineers qualify as knowledge workers. Much of the engineering expertise is technical know-how, but the point of difference is the unique knowledge that is possessed by certain staff members with years of experience as a practicing engineer. This knowledge, which is termed “tacit” knowledge (Nonaka, 1991; Polanyi, 1996) is difficult to articulate and often resides in owner’s mind only, making it largely inaccessible to the others. There is therefore a dependency on these key employees to maintain the firm’s competitive edge in the market. These characteristics clearly demonstrate that CVEng is a knowledge-based firm.

2.3 INNOVATION IN KBF – KNOWLEDGE MANAGEMENT

In the knowledge economy, the value added comes from ownership of knowledge. Correspondingly in KBFs, the value added comes from the organisational knowledge possessed by the knowledge workers (Johannessen et al., 1999). Hence innovation in KBFs must be focused on this body of individual and organisational knowledge, as it is the "wellspring of innovation" (Stewart, 1997 as quoted in Egbu & Botterill, 2001). In the context of knowledge based firms, innovation can be defined as "the application of knowledge to generate new knowledge"(Drucker, 1995). As knowledge is an intangible resource, managing it such that it can be leveraged to the firm's advantage requires "systematic efforts, and a high degree of organisation" (Drucker, 1995, p. 173). In CVEng, there is also a sense of urgency for innovation in the field of knowledge due to senior managers and directors being due to retire soon, as well as the lack of mid-level managers who drive and manage projects. If no actions are taken, the knowledge owned by these managers may be lost and thus unable to be leveraged to CVEng's sustainable and long-term competitive advantage. The need to effectively manage knowledge in an organisational setting gave rise to a relatively new and evolving management science, which is termed knowledge management (Prusak, 2001).

Despite the great deal that has been written about knowledge management (KM) in the literature, there is no authoritative definition for KM (Earl, 1999). In broad terms, KM involves identifying and mobilising organisational knowledge to gain their competitive edge (Alavi & Leidner, 2001; von Krogh, 1998). Other authors similarly define KM in terms of the creation, capture, dissemination, and application of knowledge (T. Davenport & Prusak, 1998; Robinson, Carrillo, Anumba, & Al-Ghassani, 2005).

Knowledge transfer occurs daily in CVEng. For instance, in project team meetings past project experiences are usually discussed between individuals, resulting in tacit knowledge being articulated and disseminated throughout the project team. More senior staff generally provides informal technical mentoring to junior staff. Through storytelling, site experiences, problems and solutions are discussed over more social settings such as during lunchtime or Friday after-work drinks. CVEng's intranet server hosts a variety of information ranging from engineering design spreadsheets to forms, from CAD drafting manuals to company QA policies and procedures. Despite all this inherent knowledge transfer, there has been no real effort to systematically and strategically manage it in such a way that it can be leveraged as CVEng's competitive advantage.

The lack of KM in CVEng can possibly be attributed to CVEng's rapid rate of growth over the last few decades. CVEng was originally established in 1982 as a Brisbane-based small engineering consulting firm, with two employees. Within twenty years CVEng rose to become the prominent engineering consulting firm in Queensland. In just over a decade, CVEng has grown to an international business, with approximately 300 employees in offices around Australia, the UK, and the Middle East. When the firm was small, knowledge creation and dissemination occurred fairly effectively without any need to formally and systematically manage it. However, as the firm grew in size and entered larger and more competitive markets, knowledge transfer and dissemination become more challenging due to increased staff numbers and their spread across the globe. Given the speed at which CVEng entered the global market, there has been greater emphasis on timely and quality project delivery than on internal development activities such as investments in KM and staff training.

CVEng need to adapt to new and dynamic market conditions by investing in innovation. As a KBF, the potential for innovation in knowledge, CVEng's core asset, is rife and must be exploited in order for CVEng to maintain its global market share. Investing and deploying a successful KM strategy is arguably the ideal way of encouraging innovation in CVEng.

It is essential to distinguish knowledge from information or data in order to manage it effectively. Unlike data, knowledge is intangible and dynamic (Nonaka &

Konno, 1998). It requires context, experience, interpretation, and reflection in order to be useful (T. Davenport, De Long, & Beers, 1998). As such, KM processes must be carefully tailored to provide context as well as the flexibility to allow knowledge to grow at the individual and organisational level. Further, effective KM requires an understanding of the different types of knowledge, ranging from procedural, causal, conditional, individual, and social, among many others (Alavi & Leidner, 2001), which require different treatments due to their distinct nature (Prusak, 2001). The KM literature has evolved around two basic distinctions of knowledge, namely tacit and explicit knowledge. It is within these distinctions that this thesis is written.

2.4 TACIT AND EXPLICIT KNOWLEDGE

The notion of tacit and explicit knowledge was first introduced by Polanyi (1996) and later expanded by Nonaka (1991). Explicit knowledge is knowledge that is readily "transmitted between individuals formally and systematically" (Nonaka & Konno, 1998). Tacit knowledge, on the other hand, is knowledge that is specific to an individual, which is generated from experience. It embodies an informal technical dimension, often referred to as "know-how", and a cognitive dimension, which consists of beliefs, values and mental models. Tacit knowledge is difficult to articulate as it is highly personal and is often second nature to the individual. It is this intangible knowledge that is most valuable to a firm, and hence is a fundamental source of innovation (Lee, Egbu, Boyd, Xiao, & Chinyo, 2005). In order to leverage this knowledge to the firm's advantage, tacit knowledge must be made explicit so that it can be shared, applied, and utilised by the organisation as a whole.

As a KBF, CVEng rely on their knowledge workers' explicit and tacit knowledge in order to solve engineering problems and generate value for clients. To date, the categorisation of knowledge has not occurred in CVEng, although many managers are probably subconsciously cognisant of this distinction. In order to successfully plan a KM strategy, managers need to firstly recognise and understand the different types of knowledge that exists in CVEng and how to manage them appropriately. Table 1 below shows examples of explicit and tacit knowledge in CVEng.

Table 1 – Explicit and tacit knowledge in CVEng

Business Division	Explicit Knowledge	Tacit Knowledge
Engineering	• Technical engineering design principles • Familiarity with accepted engineering standards and building codes • Flair with the use of analysis/design software packages	• Site experience • Specialist technical expertise • Preliminary design: selecting the appropriate structural framing solution for a given architecture and market conditions
Drafting	• Flair with the use of CAD or REVIT drafting software packages	• Shortcuts/tips and tricks for efficient drafting.
Project Management	• Project financial status • Construction market trends	• Client management and relations • Identifying and managing risks when submitting a job fee proposal.

The dynamic interaction between tacit and explicit knowledge is key to the creation of new knowledge and hence is a pre-requisite for innovation. Nonaka (1991) calls this interaction the "spiral of knowledge", or the SECI model (Nonaka & Konno, 1998), after the four processes of knowledge transfer: Socialisation, Externalisation, Combination, and Internalisation. The interactions between these four processes are summarised in Table 2.

Table 2 – Nonaka's four processes of knowledge transfer, (from Marwick, 2001)

TACIT TO TACIT SOCIALIZATION E.G., TEAM MEETINGS AND DISCUSSIONS	TACIT TO EXPLICIT EXTERNALIZATION E.G., DIALOG WITHIN TEAM, ANSWER QUESTIONS
EXPLICIT TO TACIT INTERNALIZATION E.G., LEARN FROM A REPORT	EXPLICIT TO EXPLICIT COMBINATION E.G., E-MAIL A REPORT

In the workplace, formal and informal individual interactions between workers provide the context for tacit knowledge to be transferred. This usually takes place through discussions in meetings, mentoring, and "storytelling" (Lee et al., 2005; Marwick, 2001; Thomas, Kellogg, & Erickson, 2001). Tacit knowledge transfer is an inherently social process, hence "socialisation". The conversion of tacit into explicit knowledge is achieved through conceptualising and articulating abstract concepts into a form that is readily understood by others (Marwick, 2001; Nonaka & Konno, 1998). This conversion occurs in the context of team dialogues and meetings. The integration of various strands of explicit knowledge, their capture, application, storage, and retrieval is referred to as "combination" (Nonaka & Konno, 1998). An example of "combination" may be to upload a report onto a shared database for others to access and use. It must be noted that by this stage, it becomes necessary to transform knowledge into information, for ease of communication and transfer. Finally, the "internalisation" of explicit knowledge takes place when an individual processes information, and upon reflection fuses it with his own tacit knowledge, hence creating new knowledge (Marwick, 2001). This perpetual cycle of knowledge conversion and creation is the primary domain of KM, and is central to organisational learning and innovation (Alavi & Leidner, 2001).

It is interesting to note that although knowledge is the main focus of KM, in practice KM requires organisations to manage knowledge, information, and data simultaneously to support the cycle of knowledge outlined previously (Vandaie, 2008). Unfortunately there is widespread confusion among both KM researchers and practitioners alike as to the nature of the knowledge being managed (Wilson, 2002). Indeed, many KM products and solutions that exist in the market are information and data management tools under the guise of "knowledge". This highlights the crucial need for a holistic view of KM to be adopted by organisations embarking on a KM innovation venture. Nonaka's (1991) spiral of knowledge is central to this holistic understanding.

2.5 KNOWLEDGE MANAGEMENT SYSTEMS

When Information Technology (IT) is deployed to facilitate and enhance the organisational processes of knowledge creation, transfer, storage, retrieval, and application, the resulting information-based system is termed a Knowledge Management System or KMS (Alavi & Leidner, 2001). Most KM scholars and practitioners agree that KMS is a IT-based system that:

- Facilitates and sustains the creation, sharing, application, storage, and dissemination of knowledge (Alavi & Leidner, 2001; T. Davenport & Prusak, 1998; Salisbury, 2003).
- Facilitates better decision-making by making available the important and relevant knowledge when required (Hung, Huang, Lin, & Tsai, 2005; King, 2005).
- Increases business value (Alavi & Leidner, 2001; Ryan & Prybutok, 2001).

The various capabilities of IT in supporting Nonaka's (1991) spiral of knowledge have been demonstrated extensively by Alavi & Leidner (2001) and Marwick (2001). Further literature search revealed two main strategies in which IT can be utilised to effectively manage knowledge, namely personalisation and codification (Hansen, Nohria, & Tierney, 1999), each with a specific emphasis on a particular process of knowledge transfer.

1. **Personalisation.** Personalisation strategy focuses on the transfer of tacit knowledge (socialisation) between individuals by promoting dialogue and communication. Zack (1999) termed this strategy as "interactive", after the human social interactions that it is based on. The personalisation strategy is prominently adopted by management consulting firms and other businesses whose services require innovative, highly customised solutions to unique problems where knowledge creation is paramount (Hansen et al., 1999; Malhotra, 2002). In this business environment, the transfer of specialist knowledge is best achieved through person-to-person interactions, as IS-based knowledge repositories cannot capture the breadth and nuance of the knowledge that are conveyed through dialogue. Initiatives such as expertise

mapping (T. Davenport et al., 1998; Marwick, 2001) and Groupware (Marwick, 2001; Ruggles, 1998) are some examples of the state-of-practice in personalisation KMS. Expertise mapping is akin to creating a directory (Yellow Pages) of experts within the company. The purpose is to enable the forging of new lines of communications between the knowledge-seeker and the knowledge-expert, which would not otherwise occur without the directory. This is especially useful in large organisations that operate in a large geographical region, where the required expertise may not exist in the local vicinity. Groupware has the capability of providing a dynamic environment whereby knowledge and information can be shared in a free-flowing manner, akin to having digitalised conversations.

2. **Codification.** Codification strategy focuses on the "externalising" tacit knowledge and capturing explicit knowledge, packaging it in parcels of information, and storing it in a communal online space where it can be accessed, retrieved, converted to tacit or knowledge, and ultimately applied to real-world problems and situations. As such, the codification strategy supports externalisation, combination, and internalisation of knowledge. The economics of this approach lies in the re-use of knowledge rather than the creation of knowledge (Hansen et al., 1999; Malhotra, 2002). Through codification, tacit knowledge is made explicit and independent of the owner, allowing the knowledge to be used and re-used by others without the need to contact the person who originally conceived the knowledge. This stands in contrast with the personalisation strategy, where the emphasis lies in tacit knowledge transfer between people. Examples of codification strategies include creating an intranet (Ruggles, 1998) and online knowledge repositories (T. Davenport et al., 1998; Ruggles, 1998). The intranet is developed to support online access to organisational information within the boundary of the organisation. Online knowledge repositories function to capture and store explicit knowledge in the form of information and data and make them available to individuals across the organisation. Examples of knowledge repositories include discussion forum threads, in which the tacit

knowledge of contributors is “externalised” into explicit knowledge, or online libraries containing technical manuals, presentations, or sales records. At first glance this repository resembles any other information databases, which stores data and information devoid of any context. It is possible, however, to provide the stored information with some context to help the KMS user turn the retrieved information into knowledge (i.e. internalisation). This can be done by careful categorisation, selection, and sorting of information (T. Davenport et al., 1998). In practice, the codification strategy requires strong, sustained investment in high-tech support due to its heavy emphasis on IT when compared to personalisation strategy, which focuses more on people interactions.

For a KMS to succeed, it is important that the firm selects and focuses on the right KM strategy, or risk failure (Hansen et al., 1999). This will be discussed in detail in the next section on critical success factors.

It is important to note that in spite of the pre-dominant role of IT in KMS, human social interactions still form the crux of all KMS, as knowledge is tied with the owner and requires human reflection and interpretation (T. Davenport et al., 1998), which IT cannot provide.

The implementation of KMS in organisations has been received with varying degrees of success. Despite the technological prowess of such implemented systems, many organisations are still finding that the IT quality alone is not enough to ensure the effectiveness of a KMS (T. Davenport & Prusak, 1998). Indeed, many technology-centric approaches to KMS have resulted in failure (Malhotra, 2002). How, then, do we ensure the success of the implementation of a KMS? To address this, we will look at the concept of Critical Success Factors (CSF) and how this concept can be applied in the context of KM and KMS.

2.6 CRITICAL SUCCESS FACTORS

Rockart (1978) defines critical success factors (CSF) as

"The limited number of areas in which results, if they are satisfactory, will ensure successful competitive performance for the organization."

The concept of CSF was initially introduced as a management methodology that enables chief executives to condense vast amounts of business information into a set of factors that are critical to the success of the business, which facilitate effective and timely decision-making. Rockart's (1978) definition is generic and therefore can be applied to KM without requiring much modification. In terms of KM, CSFs allow the focused monitoring of factors that are critical to KMS success, from which appropriate actions can be taken to improve the performance of the KMS.

The factors that contribute to the success of KM and KMS in knowledge-based firms have been studied extensively in the literature. Many of these factors were mostly derived from hypotheses (e.g. T. Davenport et al., 1998; Liebowitz, 1999), case studies (e.g. Akhavan, Jafari, & Fathian, 2006; Carrillo & Chinowsky, 2006; Robinson et al., 2005), interviews (e.g. Bishop, Bouchlaghem, Glass, & Matsumoto, 2008), and surveys (e.g. Hung et al., 2005). These factors were commonly empirically validated by Delphi studies (e.g. Holsapple & Joshi, 2000; Nevo & Chan, 2007) and surveys (e.g. Hung et al., 2005; Wong, 2005; Liu, 2011; Fong & Kwok, 2009). However, but the sample set is either insufficiently small (e.g. Nevo & Chan, 2007), too general (e.g. T. Davenport et al., 1998), or limited to particular industries and/or countries (e.g. Hung et al., 2005; Pillania, 2007; Wong, 2005; Liu, 2011). There is a scarcity in the literature specifically relating to KM and KMS applications in the construction industry, in particular engineering consulting firms. Fong & Kwok (2009) studied the CSFs for KM in the construction industry in Hong Kong, although their work was focused on contracting firms only. The work of Carrillo and Chinowsky (2006) is probably the only one that specifically addresses KM in engineering consulting firms, but the firms studied were limited to large firms (e.g. CH2M Hill and MWH). One of the aims of this study is therefore to bridge this gap by identifying the CSFs for KMS implementation in knowledge-based engineering consulting firms.

In searching for the appropriate CSFs for KMS, it is fundamental to recognise the intrinsic links between KM and KMS: that KMS is just an element of an array of other KM initiatives (Kulkarni, Ravindran, & Freeze, 2007; Liebowitz, 1999), and that its success will similarly be dependent on the success of the overall KM strategy (Jennex & Olfman, 2005). Considering the KMS in isolation will lead to problems such as the "empty library" symptom, whereby vast repositories of information (i.e. KMS) are not being exploited by knowledge workers due to the lack of "staff buy-in" or lack of management endorsement, both of which are KM success factors. Furthermore, many studies propose numerous CSFs (which number more than eight), which then raise questions over the *criticality* of these factors to the success of KM. Upon observation, and recalling Rockart's (1978) definition of CSF, it can be determined that a smaller subset of the proposed factors is critical and appropriate to the success of KM. How then, do we determine which success factors are critical? One approach adopted by Wu (2012) uses the fuzzy DEMATEL method to visualise the causal relationships between organisational goals, capabilities, and CSFs in an attempt to prioritise the CSFs meaningfully in the context of a given organisation. However, this highly quantitative and scientific approach may not be practical for this research, which is chiefly qualitative in nature. An alternative approach is to compile a list of CSFs/success factors that exists in the literature, and make an assessment of their criticality based on the frequency at which they are identified as critical. This is deemed a satisfactory approach that helps to distil the success factors into a manageable and appropriate list of CSFs, upon which further critical examination can be done. Other recent studies (Gai, 2009; Yang, 2010) have employed this approach successfully.

The number of CSF studies done on KMS implementation is fewer than those done on KM initiatives in general (see Akhavan et al., 2006; Damodaran & Olphert, 2000; Hung et al., 2005; Jennex & Olfman, 2005; Lin, 2006). Nevertheless, these studies show clear similarities between CSFs for KM and KMS. For instance, Akhavan et al (2006) identified knowledge sharing culture, training, and organisational structure as the main CSFs for KMS implementation. Similarly, Hung (2005) proposed that the CSFs for a KMS implementation include benchmark strategy and knowledge structure, organisational culture, IT, employee involvement and training, leadership and commitment from senior management, a knowledge-friendly environment and resource control, and evaluation of professional training and teamwork. This confirms the author's opinion that the success of a KMS implementation is inextricably linked with the success of KM in general.

It is also worthwhile to mention a substantial body of literature on the development of a KMS success model. The KMS success model consists of a framework that explains the causal and temporal interrelationships between the different success factors (Wu & Wang, 2006). Various KMS success models have been developed by means of synthesis between KM success factors identified in the literature with either a combination of existing organisational and management concepts and theories (Bots & de Bruijn, 2002; Lindsey, 2002; Massey, Montoya-Weiss, & O'Driscoll, 2002), or a modified IS success model (Jennex & Olfman, 2005; Kulkarni et al., 2007; Maier, 2002; Thomas Jr, 2006; Wu & Wang, 2006). Whilst it is useful to understand the interdependencies of success factors, they are not relevant to our CSF study. Recalling Rockart's definition of CSF, it can be determined that the relationship between success factors is not critical. The selection of success factors and the qualification of which factors are critical are quintessential in the CSF approach. Hence, the concept of a KMS success model will not be explored further in this research.

2.7 CSF HYPOTHESIS QUESTIONS

The results of many CSF studies show a recurring set of CSFs that are common across various industries. All of the industries studied in the literature (chemical, construction, high-tech, service) are knowledge-based and most operate in developed knowledge-based economies. Whilst the content of the knowledge differs across industries, the nature of the knowledge itself – tacit and explicit – and indeed its management are common. Hence, it would be reasonable to assume that there are no specific CSFs that are characteristic to an engineering consulting firm, itself being a KBF. The success factors for the implementation of a KMS identified in the literature are summarised in Table 3. From Table 3 it can be observed that management support and leadership, a clear KM strategy, knowledge-sharing culture, organisational infrastructure, employee motivation, and measurement are the success factors that are most frequently reported by researchers. Management support, in particular, is reported in all studies listed in Table 3. The availability of resources as a CSF for KMS does not appear as frequently in the literature as other CSFs like training and IT infrastructure, but it is highly relevant to the construction industry as reported by Fong & Kwok (2009) in their study of contracting firms in Hong Kong. Furthermore, in the SME field, resource is a CSF that features prominently in many KM studies, thereby validating its selection as a CSF for KMS implementation in SMEs. Based on these findings, the hypothesised critical success factors for KM/KMS implementation in a knowledge-based engineering firm are as follows:

1. Management support and leadership.
2. KM strategy
3. Performance measurement and evaluation
4. Organisational infrastructure for KM
5. Employee motivation
6. Knowledge-sharing culture
7. Availability of resources

Table 3 – Summary of KM/KMS success factors identified in the literature

KM/KMS success factors	Davenport et al (1999)	Liebowitz (1999)	Damodaran & Olphert (2000)	Holsapple & Joshi (2002)	Hasanali (2002)	Wong (2005)	Jennex & Olfmann (2005)	Hung et al (2005)	Akhavan et al (2006)	Al-Mabrouk (2006)	Lin (2006)	Nevo & Chan (2007)	Bishop et al (2008)	Yang & Yeh (2010)	Gloet & Samson (2012)	Sedighi & Zand (2012)	TALLY
Management support and leadership	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
Culture	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	14
KM strategy, clear definition and objectives	✓	✓	✓			✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	13
Organisational infrastructure (e.g. CKO roles)	✓	✓			✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	12
Rewards, incentives, employee motivation	✓	✓				✓	✓			✓	✓	✓	✓	✓	✓		10
Measurement	✓		✓	✓	✓	✓		✓		✓	✓		✓			✓	10
Training			✓			✓	✓	✓	✓	✓		✓		✓	✓		9
Technical infrastructure (IT)	✓	✓			✓	✓	✓			✓			✓		✓	✓	9
Availability of resources			✓	✓		✓	✓	✓		✓						✓	7
Processes				✓		✓				✓	✓						4
Integration into organisational routine			✓				✓					✓	✓				4
Knowledge structure and architecture							✓		✓								2
Human resource management						✓				✓				✓		✓	3
Ability to generate innovation											✓						1
Marketing										✓							1
Quality of knowledge												✓					1
System quality (ease of use, accessibility)												✓					1

The author hence proposes the following hypothesis questions:

H1: IS MANAGEMENT SUPPORT A CSF FOR KM/KMS IMPLEMENTATION IN A KBF?

As with most change programmes, the support of senior management is vital to the success of a KM initiative (T. Davenport et al., 1998). The type of managerial support varies from operational, motivational, to financial. Financial support is arguably the most important and the easiest to measure, as it is quantifiable and therefore can be monitored and benchmarked. Top managers need to be the catalyst for the KM initiative (Holsapple & Joshi, 2000) by communicating the benefits of the initiative to the organisation and demonstrating their close involvement with the initiative (Bishop et al., 2008). They also act as role models for the other employees, who can then imitate their behaviour and ultimately create a healthy culture whereby KM can thrive and succeed (Wong, 2005). However, in order to promote ongoing KM success, Holsapple and Joshi (2000) asserted that this level of support must be exercised by managers throughout the hierarchy of the organisation. Indeed, this will ensure that top-driven KM efforts are implemented throughout the whole organisation.

Although most KM researchers and practitioners agree that a successful KM implementation will result in improved organisational performance, there is little empirical evidence to prove this link (T. Davenport & Prusak, 1998; Kulkarni et al., 2007). This is due to presence of many factors other than KM influencing organisational performance, such as technology, staff efficiency, revenues, among many others (Wong, 2005). Furthermore, the immediate benefits of KM are intangible, such as greater work efficiency and improved knowledge asset (Kulkarni et al., 2007). This difficulty in demonstrating tangible benefits to management may influence certain managers who base their support on traditional ‘hard’ measures, such as ROI (Carrillo & Chinowsky, 2006; Robinson et al., 2005; Wong, 2005). There is a need for management to embrace ‘soft’ measures as well as traditional ‘hard’ measures (Wong, 2005) in order to ensure continual management support.

H2: IS KM STRATEGY A CSF FOR KM/KMS IMPLEMENTATION IN A KBF?

Having a clear and well-planned KM strategy is crucial to the success of the KM (Bishop et al., 2008; T. Davenport et al., 1998; Liebowitz, 1999). This involves setting clear goals and objectives, which are aligned with the firm's competitive strategy. Management holds a key responsibility in ensuring that the KM goals and objectives are communicated to all staff and are widely understood and accepted. Zack (1999) reports that successful knowledge firms are able to articulate the link between KM strategy and what staff members at all levels of the organisation need to do to execute the strategy. This is also confirmed by Bishop et al (2008), who studied KM projects in construction companies in the UK and the USA.

Once clear objectives are set, the firm is able to identify its core competencies and their associated knowledge that support these competencies (Liebowitz, 1999; Salisbury, 2003). A knowledge gap analysis should be conducted to examine the state of knowledge required to fulfil the KM strategy. An appropriate knowledge strategy (i.e. personalisation or codification) can then be selected and executed to bridge this gap. The knowledge strategy should suit the nature of the core knowledge to be managed, namely a personalisation strategy for tacit knowledge, or a codification strategy for explicit knowledge. Hansen et al (1999) found that firms that excel in KM focus on one strategy and use the other as a support. For instance, in the 1990s, Ernst & Young were constantly growing at rates of 20% by focusing their KM efforts on the codification strategy. Ernst & Young's managers realised that the greatest value for their clients come from the re-use of existing knowledge in different contexts. They duly invested on electronic knowledge repositories that capture, store, and disseminate codified knowledge, allowing the re-use of knowledge. As a result, their consultants are able to provide high-quality and reliable advice to clients at a much faster rate, leading to greater efficiency and revenues.

H3: IS PERFORMANCE METRICS A CSF FOR KM/KMS IMPLEMENTATION IN A KBF?

If you can't measure it you can't manage it (Wong, 2005). The establishment of a framework to measure the performance of a KM system is crucial in order to assess its effectiveness, and to support its continuous improvement. The main challenge in establishing suitable performance metrics lies in the difficulty in demonstrating tangible benefits to management (Carrillo & Chinowsky, 2006; Robinson et al., 2005; Wong, 2005). Since KM benefits tend to be intangible, management must embrace both 'soft' and 'hard' measures to ensure a successful implementation of the KMS. Soft measures may include intellectual capital metrics and the balanced scorecard (Wong, 2005).

H4: IS ORGANISATIONAL INFRASTRUCTURE A CSF FOR KM/KMS IMPLEMENTATION IN A KBF?

The management of knowledge and its processes is a complex task that requires specialist attention. A great deal of the literature recommended the establishment of knowledge roles, in particular the Chief Knowledge Officer (CKO), who would be responsible for all knowledge-related efforts in the organisation, as well as the main driving force behind the KM programme (Bishop et al., 2008; T. Davenport et al., 1998; Liebowitz, 1999; Ruggles, 1998; Wong & Aspinwall, 2005). The CKO is an indicator of top management's commitment to KM. Bishop (2008) also recommended the appointment of KM champions and sub-champions at all levels of authority and accountability, whose function is to act as role models and leaders in KM efforts. If the KM strategy involves the building of a knowledge repository, then Zack (1999) recommended that a knowledge editor be in charge of the quality of content and context. The knowledge editor selects, filters and applies context to the incoming knowledge by means of careful tagging, sorting, and indexing. The editor would also be responsible for maintaining the currency and validity of the repository, replacing out-dated knowledge with the latest best practice. In this way the repository would be scalable to a meaningful and reasonable degree to the extent that the users find it relevant and effective. The establishment of such organisational infrastructure requires financial support as well as flexibility in organisational restructuring to create the so-called “knowledge roles”.

H5: IS EMPLOYEE MOTIVATION A CSF FOR KM/KMS IMPLEMENTATION IN A KBF?

Employee motivation and commitment have been identified as a critical success factor for KM/KMS (Davenport et al, 1999; Liebowitz, 1999; Wong, 2005; Jennex & Olfmann, 2005; Lin et al, 2006; Nevo & Chan, 2006; Bishop et al, 2008). The many examples of KMS project failures demonstrate that high quality KM systems do not guarantee its usage (Kulkarni et al., 2007). Indeed, the social aspects of KM simply cannot be addressed by technology (Thomas et al., 2001), a phenomenon which Ackerman (2000) calls the “social technical gap”. The social factors involved with KM implementation are complex by nature, and is not well understood (Thomas et al., 2001). A possible inhibitor to employee motivation and commitment may be the lack of employee’s awareness of KM. There is a tendency for people not to commit if they do not understand how KM will benefit them, which necessitates management to establish clear KM strategy and communicate its benefits to all staff (refer hypothesis question H2 For discussions on KM strategy)

A successful KM/KMS implementation requires continual employee commitment (Malhotra & Galletta, 2003). Malhotra & Galletta (2003) proposed that there are three ways to achieve commitment: by compliance, identification, and by internalisation. Compliance refers to the establishment of rewards and punishment schemes in an effort to define desirable behaviour. This approach requires a certain exertion of manipulative control by management, which may not be well received by staff members. Identification refers to the establishment of KM “champions”, who act as role models whose behaviour other employees can aspire to imitate and emulate. Identification relies heavily on the selection of the role models, and can only work when there is strong affiliation between the role model and the other staff members. In contrast to these two approaches, internalisation brings about behavioural changes at a deeper level by promoting and internalising values, which serve as guides in sustaining the desirable behaviour. This approach is likely to have longer-lasting results, as values are longer lasting than rewards or social recognition. In order for the internalisation approach to be effective there is a need for a KM-friendly culture to exist in the firm. This will be discussed in hypothesis H6.

A common way to motivate knowledge workers to embrace KM is to provide incentives such as reward schemes, which promote knowledge-sharing behaviour. Incentives can be financial or non-financial, or both (Kulkarni et al., 2007). However, the literature is divided as to the effectiveness of financial or non-financial incentives (Bishop et al., 2008; Kulkarni et al., 2007). Tangible, financial rewards tend to have greater initial impacts, as they are highly visible to fellow workers. However studies have shown that their effects are short-lived. They also tend to ensure compliance, not commitment (Kulkarni et al., 2007; Malhotra, 2002; Malhotra & Galletta, 2003). Non-financial rewards include recognition from peers, the organisation, and the industry as an “expert”. Bishop et al (2008) reported that non-financial rewards are more effective in the construction industry. In order for incentives to be effective, Davenport et al (1998) suggested that KM-related incentives need to be long-term, and should tie in with general performance appraisal and review structures.

H6: IS KNOWLEDGE-SHARING CULTURE A CSF FOR KM/KMS IMPLEMENTATION IN A KBF?

A great majority of KM research has highlighted culture as a CSF for KM/KMS implementation. In a survey study of 431 US and European organisations in 1997, Ruggles (1998) identified culture as the biggest inhibitor to a successful KM. Culture can be defined as “embedded values and preferences about what a firm should strive to attain and how to achieve it” (Kulkarni et al., 2007). Drucker (1996, as quoted in Bishop et al., 2008)) defines culture as the “corporate glue” that binds employees to the organisational objectives. Culture is defined and driven by management.

Davenport et al (1998) recommended that an ideal and friendly knowledge-sharing culture has the following characteristics:

1. Positive orientation to knowledge. Knowledge workers are independent, curious learners. Managers encourage knowledge creation and application.

2. People are not inhibited from sharing knowledge.

There is great emphasis on a collaborative culture where knowledge workers perceive each other as partners, not competitors (Kulkarni et al., 2007; Wong, 2005). A competitive culture usually promotes selfish behaviour such as knowledge hoarding, which stems from the thinking that job security/prospect is tied to personal expertise (T. Davenport et al., 1998; Kulkarni et al., 2007). Liebowitz (1999) also found that knowledge hoarding behaviour is due to the fear of losing ownership of knowledge.

There also exists the fear of sharing knowledge generated from project failures and mistakes (T. Davenport et al., 1998; Wong, 2005), which is evident in a large engineering company studied by Davenport et al (1998). A knowledge-friendly culture views mistakes as a key source in learning (Wong, 2005), and does not inhibit workers from sharing failures from their colleagues.

H7: IS THE AVAILABILITY OF RESOURCES A CSF FOR KM/KMS IMPLEMENTATION IN A KBF?

Holsapple and Joshi (2000) identified resources as a critical success factor for KM. The availability of financial, time, and human resources determine the extent to which KM and KMS is applied in an organisation. Whilst most other researchers do not consider resources as a CSF, Wong (2005) argued that it is a CSF that is specific to small to medium sized firms. According to Wong (2005), small to medium sized firms often operate on smaller, tighter budget, which critically limits their ability to invest in a risky, peripheral innovative venture such as KM. In order to make an investment in KM worthwhile, Wong (2005) suggested that managers consider KM as a central investment, not as a “nice-to-have” business programme. Incidentally, the availability of resources is also an indicator of management support, which in itself is a resource (Davenport & Volpel, 2001).

Investing in KM can be expensive (T. Davenport et al., 1998; Hansen et al., 1999). For example, Davenport et al (1998) reported that Ernst & Young spends 6% of its total revenue on KM, while McKinsey & company spends 10%. A suitable performance metrics can be established to link improved performance and efficiency to KM, which should give more confidence to managers to maintain – if not increase – their investment in KM (refer hypothesis H3 for discussions on measurement).

2.8 CONTINGENCY FACTORS

It is important to recognise that the same critical success factors do not apply to all situations uniformly. For instance, a small engineering consulting firm with narrow profit margins may find that the availability of financial resources is more critical to the successful implementation of a knowledge management system than a large, multi-national consulting firm would. In contrast, a large multi-national firm with offices around the world may find that IT-supported communication channels such as video-conferencing or Groupware is more critical to tacit knowledge transfer than a small firm, where knowledge transfer happens readily in the limited space of the office.

The contingency theory will be used as a lens from which the critical success factors for KMS implementation in knowledge-based firms will be selected and validated in the context of CVEng. The contingency theory recognizes that no "one size best fits all" (Shenhar, 2001; Tarter & Hoy, 1998), and that the critical success factors for KMS vary depending on the environmental, financial, and managerial conditions of the firm. It is proposed that the contingency factors for KMS implementation are:

1. Size of the firm
2. Geographical spread of the firm
3. The type of industry

2.9 CRITICAL SUCCESS FACTORS MODEL

The proposed critical success factors model with the above hypothesised correlations and contingency factors are shown in Figure 2 below. This research model is tested and validated in the next stages of research.

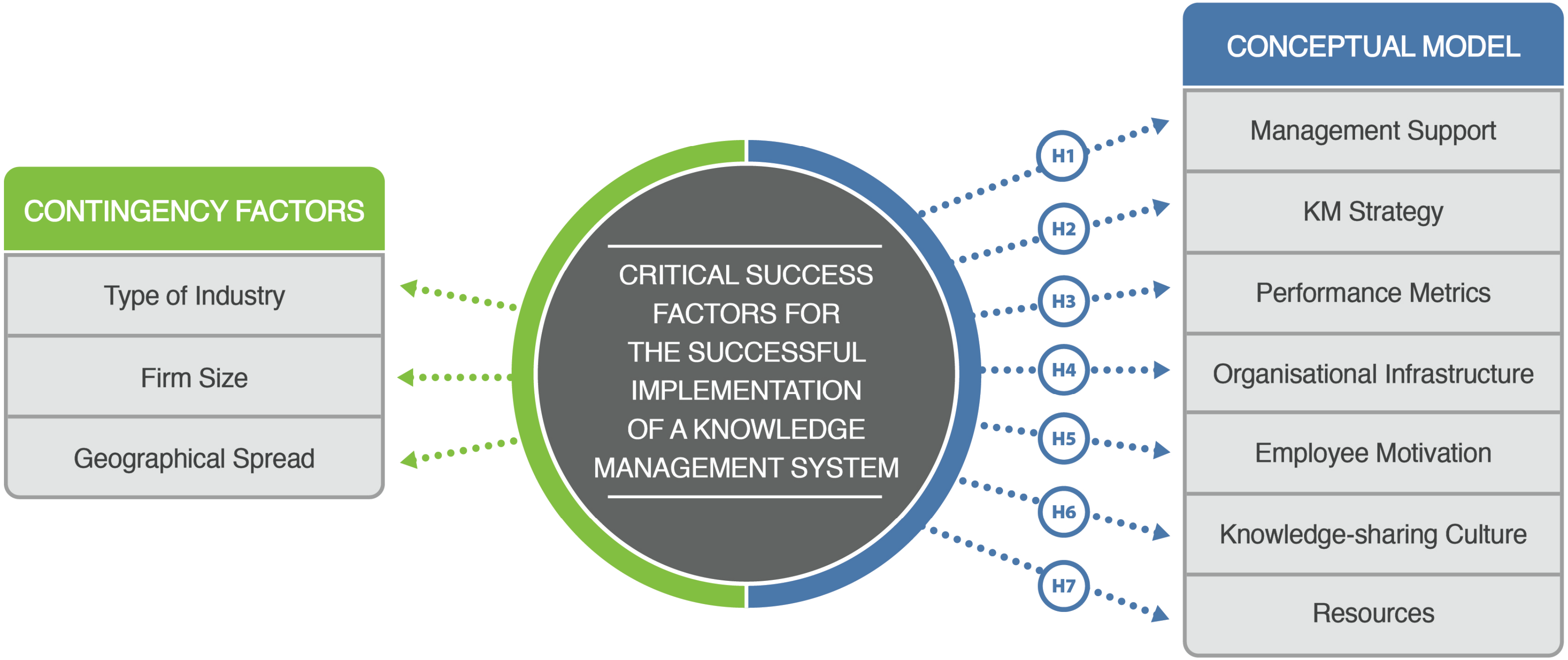

Figure 2 – CSF Research Model

3. VALIDATION OF THE CSF MODEL

The next step in this research is the validation of the hypothesised research model developed in the preceding literature review. The Delphi method has received widespread popularity in Information Systems (IS) research and in other fields where the answer to the research question is not well defined. This section of the thesis provides a brief overview of the Delphi method, in which the relevance of the Delphi method in relation to this research will be investigated. This section also outlines the research design using the Delphi method, followed by the data collection & analysis methods. This section concludes with the final validated CSF research model.

3.1. DELPHI METHOD

The Delphi method was first developed by the RAND Corporation in the 1950s as a research method that solicits expert opinions on a complex research problem, for which there is no precise information available (Linstone & Turoff, 2011). The method emphasises on structuring group communication processes in a systematic manner in order to achieve a reasonable convergence of opinion from a group of experts (Linstone & Turoff, 2011; Gupta & Clarke, 1996). The research data – i.e. expert opinion – is typically collected by means of several rounds of intensive questionnaires, which generates a series of qualitative and quantitative data for analysis. The analysis findings will then determine the form and content of subsequent questionnaires, and so on until the group opinion is formed and is stable (Gupta & Clarke, 1996).

The primary features of the Delphi method are fourfold:

1. **Statistical group response.** The questionnaires are designed so that the answers can be analysed quantitatively and statistically (Landeta, 2006). This can be achieved by means of a ranking-type response, such as the Likert sliding scale from 1-5, where 1 represents least relevance and 5 most relevance.

2. **Anonymity of Delphi participants.** This allows the participants to freely express their individual opinions without the tendency to conform to the group's dominant opinion (Skulmoski & Hartman, 2007). This technique also avoids any distortions in the opinions that may result from direct confrontation of experts (Okoli & Pawlowski, 2004) due to their status or personality (Landeta, 2006).

3. **Controlled feedback.** The research information generated during data collection is fed to a study group coordinator who processes the data, eliminates irrelevant information, and formulates new questions based on the received information (Landeta, 2006). This key feature enables the Delphi study to take a focused approach needed to solve a specific research problem, or to expand the study to include new parameters previously unidentified by the researcher. This flexibility in research design is one of the Delphi method's unique features.

4. **Iteration of data collection.** The repetition of questionnaire rounds gives the participants an opportunity to reconsider their opinions in light of the information received from the other participants (Landeta, 2006). In this way, the iteration of data collection facilitates the gradual formation of group opinion.

The number of rounds of questionnaires depends on the stability or convergence of the responses, not necessarily consensus (Linstone & Turoff, 2011). Coates (as quoted in Linstone & Turoff, 2011) observed:

"The value of the Delphi is not in reporting high reliability consensus data, but rather in alerting the participants to the complexity of issues by forcing, cajoling, urging, luring them to think, by having them challenge their assumptions."

This is in contrast to a more traditional panel or forum where consensus is desired and is sometimes forced, leading to distortions in research data (Linstone & Turoff, 2011).

The literature review on the implementation of a KMS has identified a knowledge gap in the application of critical success factors in the context of an engineering KBF. The scarcity of research on this field and the complexity of the research question make Delphi an ideal research method for this study. The Delphi method is well suited in dealing with open-ended problems as the structured group communications process facilitates independent thought and the gradual formation of group solutions (Gupta & Clarke, 1996). Further, the selection of industry experts in the Delphi panel enables the study to adopt a more focused approach in attempting to identify the relevant CSF's by taking advantage of the experts' depth of knowledge in KM and their field of expertise. Whilst the author has developed a research model with several hypothesised CSF's based on the literature review findings, the Delphi method may in fact reveal other CSF's that may eventually result in the research model being amended.

For all its strengths, the Delphi method also has several shortcomings (Gupta & Clarke, 1996; Yousuf, 2007; Linstone & Turoff, 2011) as listed below:

1. The poor selection of experts will tend to produce erroneous results, and may lead to instability of responses and poor convergence of opinions.
2. Lack of participation and low response rate can result from the experts' lack of motivation to participate, or the perception that the study is too lengthy or pointless.
3. Poorly designed questionnaires can confuse the experts, which may result in the experts giving undeveloped responses due to their lack of understanding on the research matter.
4. The iteration of data collection may also frustrate the experts, some of whom will inevitably provide similar responses.
5. The consensus achieved in Delphi may not be a true consensus, resulting from a poorly designed close-ended questionnaire and the tendency of the Delphi method to eliminate extreme opinions.

6. The method relies on both the researcher and the experts having excellent written communication skills, as all interactions are done on paper.
7. The Delphi method requires considerable time and commitment on the part of the experts.

The planning and execution of the Delphi method in this research take into account the above commonly recognised limitations of the method. This is described in more detail in the next section.

3.2 CSF RESEARCH DESIGN

This section describes the application of the Delphi method to the data collection component of this research. The objective of the Delphi study is to distil a convergent list of CSF's from the Delphi experts that is then used to validate the research model. The eventual research outcome is qualitative, however successful application of the Delphi technique will require the responses to be quantitative so that they can be analysed statistically. In order to achieve this, the questionnaires requested the experts to rank the relevance of the hypothesised CSF's in order of importance.

In order to accurately determine the effects of contingency factors on the CSF research model, the research would require a greater sample size such that there exist groups of at least three firms having similar attributes. For the three proposed contingency factors there are 3! = 6 possible combinations of attributes that need to be studied, which would require a sample set of 18 people. This sample size is beyond the scope of this research. Further studies should be conducted with greater sample size if the clear relationships between the contingency factors and the CSF's are to be defined and understood.

The data collection consists of two broad activities, namely the selection of experts and the Delphi questionnaire rounds.

3.2.1. EXPERT SELECTION

The quality of any Delphi study chiefly depends on the quality selection of appropriate experts. The author employed a procedure for selecting the experts similar to that described by Okoli (2004).

1. **Prepare a knowledge resource nomination worksheet (KRNW).** The KRNW aims to categorise the experts in order to prevent any important categories of experts from being overlooked. As this research is targeted at KBF's in Australian construction industry, the expert categories involve architects, engineers, developers, and contractors who have substantial experience in managing their respective businesses. Prior exposure to KM is desirable, but not necessary.

2. **Populate the KRNW with names.** Potential experts were identified under the various categories. The author employed the professional network of contacts available to CVEng and sought advice from his colleagues regarding the suitability of the potential experts for the Delphi project. The experts consisted of senior managers of firms in the Australian construction industry. The author intended to invite two experts per category, amounting to eight experts in total. This ensures that each category is sufficiently represented while maintaining a manageable number of participants. The Delphi method does not require a large number of participants, as it is a focused research method aimed at achieving reasonable consensus of opinions in a group of experts.

3. **Invite experts.** The author approached the experts individually by means of emails, telephone, or by direct meeting. During the initial approach, the experts were briefed on the research study and the Delphi method.

3.2.2. DELPHI QUESTIONNAIRE ROUNDS

The Delphi study was carried out in three rounds as outlined below:

1. **Round 1 – Brainstorming of CSF's.** In this round the experts were asked to identify the CSFs for KMS implementation and rank them in order of

relevance. They were also asked to propose any other CSF's that they perceive as being relevant. It must be noted that the experts were not briefed on the literature review findings at this stage. This is also a way of validating the construct validity of the research model. The first questionnaire was designed with a preamble that gives a brief overview of the research topic, the Delphi method, and conditions of participation. The purpose of the preamble was to give sufficient information to the experts to eliminate confusion on the research topic and to give the experts the best possible chance to give quality answers for the next round of questionnaire.

2. **Round 2 – Ranking of CSF's.** Following the analysis of the first round findings, the second questionnaire reported the first round results to the experts. The experts were then asked to re-rank the hypothesised CSF's whilst giving due consideration to the other experts' opinion in the previous round. Any new CSF's that were identified in the first round were also fed back into the expert panel and included in the ranking.

3. **Round 3 – Refinement of CSF list.** In the final round, the results of the second round were fed back to the experts. Where the expert's round 2 ranking differed substantially from the group mean ranking, the experts were asked to explain why this was so. Finally, the research findings were synthesised into a convergent set of CSF's, which were then used to validate the research model.

In each round, the statistical data (rankings) will be analysed to give mean ranks and sample standard deviation. The convergence of opinions was qualitatively measured using Kendall's coefficient of convergence W, in keeping with the Delphi methodology outlined by Okoli (2004). The value of W ranges from 0 to 1, indicating no to perfect consensus respectively. Schmidt (1997) proposed that a weak consensus exists for $W < 0.3$, moderate consensus for $W = 0.5$, and strong consensus for $W > 0.7$. For the purposes of this study, the Delphi rounds were to be terminated once $W > 0.7$ is achieved for the CSF list.

The questionnaires were distributed via email in order to maximise the chance of prompt return of questionnaires. The author requested a one-week deadline for the return of questionnaires. Follow-up calls were made in the event that the experts did not meet this proposed deadline.

3.2.3. PILOT STUDY

The success of the Delphi study also depends on the quality of the questionnaire. Okoli (2004) suggested that, since the questionnaire is more time-intensive than a traditional survey, no single questionnaire takes more than 30 minutes to complete. In order to test the quality of the questionnaire, and in order to overcome the potential shortcomings of Delphi as described previously, the author conducted a pilot study in which a number of the author's colleagues in CVEng were given the pilot questionnaire to complete. The feedback received from this group were then discussed with the group and improvements made to the questionnaire before they were sent out to the expert panel.

3.3 DELPHI STUDY

The initial invitations and QUT Participation Consent Forms were sent out by email to the potential Delphi participants. In compliance with QUT's research ethics policy, the Delphi study did not start until all participants returned signed copies of the consent forms. Out of 8 invitees, 7 agreed to participate in this study.

3.3.1. DELPHI ROUND 1

Round 1 Delphi commenced in November 2011 with a sample set of seven participants. All seven participants returned their questionnaires on time. The sample set consists of senior professionals in the Australian construction industry, which includes architects, engineers, contractors, and project managers. All participants are based in Australia. The participants' ages vary from 40 to 65, indicating the extensive experience they have in the industry. Their companies vary from local practices with 100 staff or less to large multi-national contractors with over 500 staff just in Australia. Figures 3 to 5 illustrate the demography of the Delphi participants. Despite the relatively small sample size, the Delphi panel is a fair representation of the Australian construction industry.

Subsequent discussions on the Delphi study will be done anonymously so as to protect the identity of the Delphi participants.

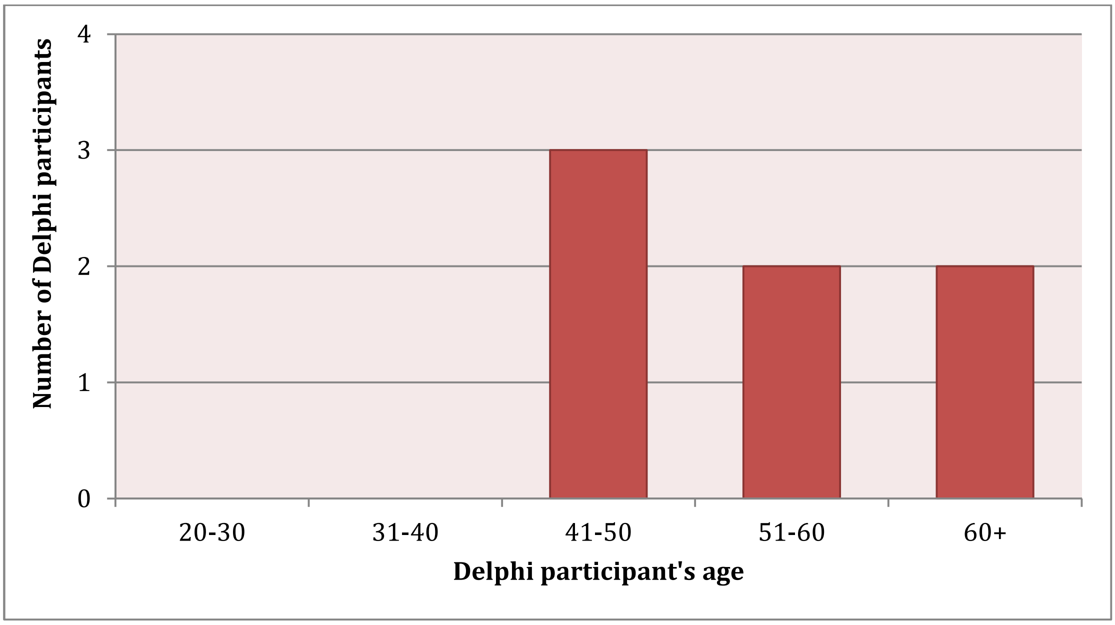

Figure 3 – Age of the Delphi participants

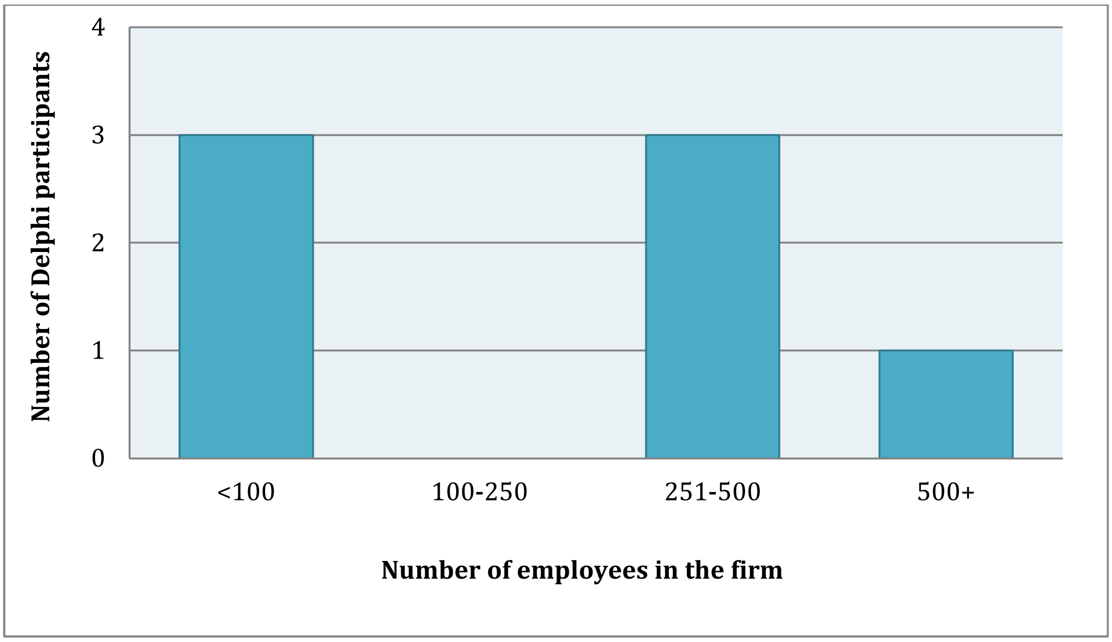

Figure 4 – Size of the Delphi participants' firms (number of staff)

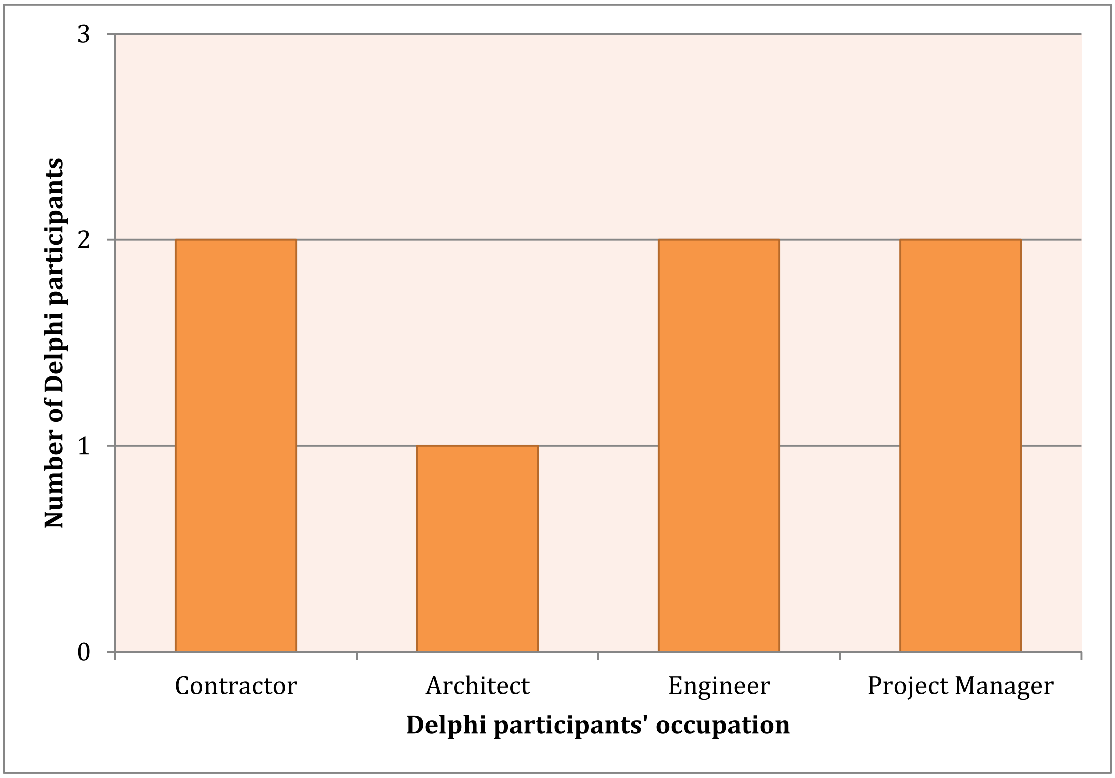

Figure 5 – Occupation of the Delphi participants.

All participants have had involvement with KM in their careers. 70% of participants have had more than 10 years involvement with KM. The majority of participants have used, promoted, or contributed their knowledge towards the KMS. Only one participant has designed and maintained a KMS. 57% of participants reported their firm as having a KMS in operation as part of their daily business operations. The most common types of KMS in the participants' firms are knowledge databases and company intranet. Other types of KMS include online discussion forums, expert directory, collaborative software, best-practice manuals, and project document control system. Figures 6-7 illustrate the participants' involvement with KM.

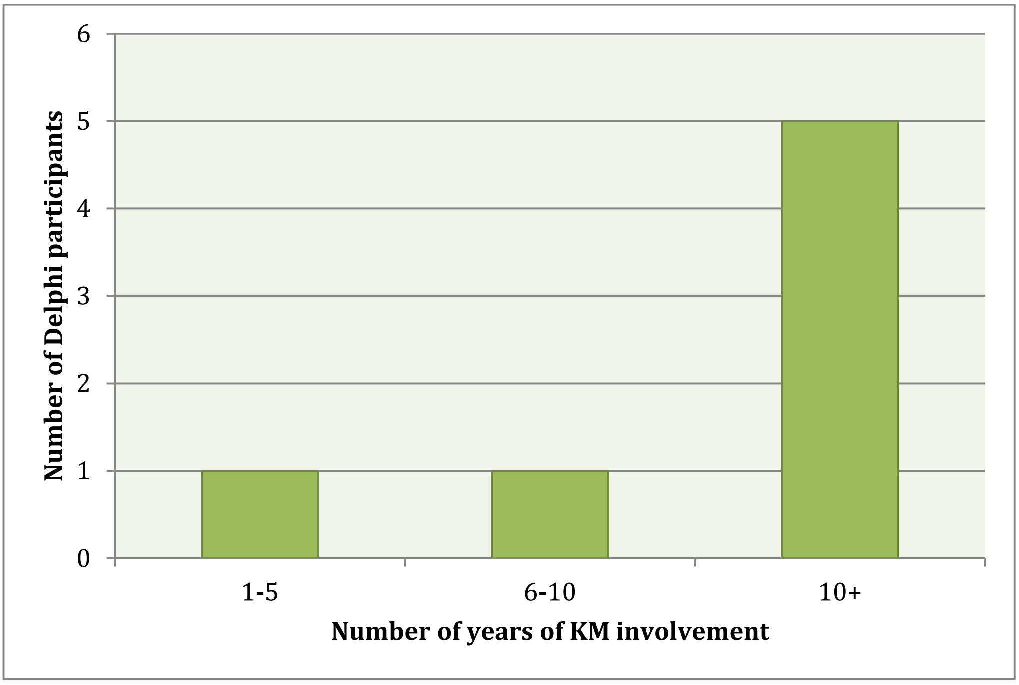

Figure 6 – Term of the Delphi participant's involvement with KM

Type of KM involvement	Delphi A	Delphi B	Delphi C	Delphi D	Delphi E	Delphi F	Delphi G
Promoter			✓	✓	✓	✓	
User	✓	✓			✓	✓	
Contributor	✓	✓			✓	✓	
Maintenance					✓		
Designer					✓		
Other							✓

Figure 7 – The Delphi participants' involvement with KM (real names withheld in confidence)

The first Delphi round asked the participants to identify the CSF's that they feel are essential towards the implementation of a KMS. The participants were also asked to rank the CSF's in order of importance, a ranking of one being most essential and eight being least essential. The first round questionnaire can be found in Appendix B.

The responses received varied considerably and needed to be consolidated into a generic list that is more useful and simpler to understand. To this end, the author studied the CSF responses and compared them with the research model. It was found that there was close agreement between the Delphi responses and the CSF's identified in the research model: all seven postulated CSF's were mentioned in the Delphi participants' responses. However, the Delphi study identified another CSF that is not included in the research model: the quality of the KMS. The author noted that this CSF was in fact identified in the literature review (refer Section 2) but was not incorporated into the research model due to the relatively small number of papers that identified this CSF.

The rankings received in Round 1 were not analysed, as there was considerable repetition and similarities in the CSF responses of some participants.

3.3.2. DELPHI ROUND 2

In Round 2, the Delphi participants were presented with a consolidated list of CSF's identified in the previous round. Each CSF was described using key words and quotes that the participants used in Round 1, in order to facilitate better and easier comprehension by the participants. They were then requested to rank the CSF's in order of priority, 1 being the most essential, and 8 being the least so. The Round 2 questionnaire can be found in Appendix B

Six out of the seven participants returned their questionnaires in time. Due to time constraints, the researcher decided to progress the analysis of the data with the reduced sample set.

The CSF rankings in Round 2 are shown in Table 4 below. For the purposes of statistical computation, let i be the CSF, $r_{i,j}$ be the rank given to CSF i by participant number j. Let m be the number of participants and n be the total number of CSF's.

Table 4 – CSF Rankings $r_{i,j}$ in Delphi Round 2 (m = 6)

CSF *i*	Judge *j*					
	1	**2**	**3**	**4**	**5**	**6**
1	1	1	3	1	1	5
2	7	5	5	5	3	2
3	8	7	8	8	7	4
4	5	2	6	7	6	7
5	3	8	7	2	5	8
6	2	3	2	4	2	6
7	4	6	4	6	8	1
8	6	4	1	3	4	3

Convergence of rankings is measured using Kendall's coefficient of concordance *W*, computed as follows.

$$W = \frac{12S}{m^2(n^3 - n)}$$

where *m* and *n* are defined above, and *S* is the sum of squared deviations, defined as follows.

$$S = \sum_{i=1}^{n} (R_i - \bar{R})^2$$

R_i is the total rank given to CSF *i*, and $\bar{R}$ is the mean of these total ranks.

$$R_i = \sum_{j=1}^{m} r_{i,j}\,; \quad \bar{R} = \frac{1}{2} m(n + 1)$$

The calculations for *W* are shown on Table 5.

Table 5 – Calculation of Round 2 *W* value (*m* = 6)

CSF *i*	R_i	$(R_i - \bar{R})^2$
1	12	225
2	27	0
3	42	225
4	33	36
5	33	36
6	19	64
7	29	4
8	21	36
Total *S*		**626**

$$W = \frac{12 \times 626}{6^2(8^3 - 8)} = 0.414$$

Round 2 achieved a weak to moderate convergence with *W* = 0.414. The participants generally agree that CSF1 – management support is the most important CSF, having a mean rank of 2.00. Only one participant gave CSF1 a rank higher than 3. CSF6 – knowledge sharing culture came second with a mean rank of 3.17, followed by CSF8 – quality of KMS. Based on the mean ranks in Round 2, the CSF's group rankings are summarised in Table 6 below.

Table 6 – Group Ranking of CSF's in Round 2

Number	Critical Success Factor	Rank
CSF 1	Management support	1
CSF 2	Develop a KM strategy	4
CSF 3	Performance metrics	8
CSF 4	Develop KM infrastructure	6
CSF 5	Employee motivation and buy-in	7
CSF 6	Culture of knowledge sharing	2
CSF 7	Availability of resources	5
CSF 8	Quality of KMS	3

The group rankings correlate well with the literature findings shown in Table 3. For instance, the top ranking CSF1 – management support has been consistently identified in all the literature reviewed. Likewise, CSF6 – knowledge-sharing culture, which was ranked second by the group, has been identified in 85% of the literature studied. However, CSF8 – quality of KMS (ranked third) was only mentioned in one paper out of the 13 papers studied. This could be explained by the fact that most of the papers reviewed assumed that the quality of KMS is good and not at fault (Nevo & Chan, 2007). In practice, the quality of the KMS would play a key role in ensuring the success of its implementation, as the Delphi participants observed in their experience.

3.3.3. DELPHI ROUND 3

The Round 3 questionnaire began with a review of Round 2 results. Following the recommendations of Schmidt (1997), three pieces of information were fed back to the participants. First, the group mean for each CSF was given and compared with the participants' Round 2 rankings. As such the questionnaires were individually tailored to suit each participant's rankings. Second, the degree of convergence of Round 2 opinions was reported as being weak to moderate. Third, for each CSF, the percentage of participants who ranked the CSF in the top half was reported. The second and third pieces of information gave the participants a sense of the level of consensus achieved. The participants were then asked to justify their Round 2 rankings where theirs differ substantially from the group mean ranking. Finally, the participants were asked to re-rank the CSF's, taking the group opinion into consideration. Refer Appendix B for the Round 3 questionnaire.

The sample set in Round 3 consisted of six participants as per Round 2. Some of the expert's explanations of their Round 2 rankings were fed back into the group anonymously in order to facilitate convergence of group opinion. All six participants returned the questionnaires with rankings.

Table 7 below shows the calculations for Kendall's coefficient *W* in Round 3. The sample set consists of six people.

Table 7 - Delphi Round 3 results and *W* calculations (*m* = 6)

CSF *i*	Judge *j*						R_i	$(R_i - \bar{R})^2$
	1	2	3	4	5	6		
1	1	1	3	1	1	1	8	361
2	7	5	5	5	3	5	30	9
3	8	7	8	8	7	4	42	225
4	5	2	6	7	6	6	32	25
5	3	8	7	2	5	8	33	36
6	2	3	2	4	2	7	20	49
7	4	6	4	6	8	2	30	9
8	6	4	1	3	4	3	21	36
Total *S*								750

$$W = \frac{12 \times 750}{6^2(8^3 - 8)} = 0.496$$

In Round 3 a moderate convergence of expert opinion was achieved with *W* = 0.496. This is an improvement from Round 2 results, where only weak to moderate convergence was achieved with *W* = 0.414. Five of the six Delphi participants did not change their CSF rankings from Round 2. Better convergence was achieved due to one participant modifying his rankings to better suit the group mean rank.

Figure 8 below summarises the Delphi findings and graphically illustrates the convergence of expert opinions in the Delphi process. The listing of CSF's on the right hand side of the diagram shows the relative rankings of the CSF's if perfect convergence was achieved (*W* = 1.0). The diagram shows how the *relative* ranking between the CSFs at Round 3 corresponds to the ranking that could be achieved at perfect convergence.

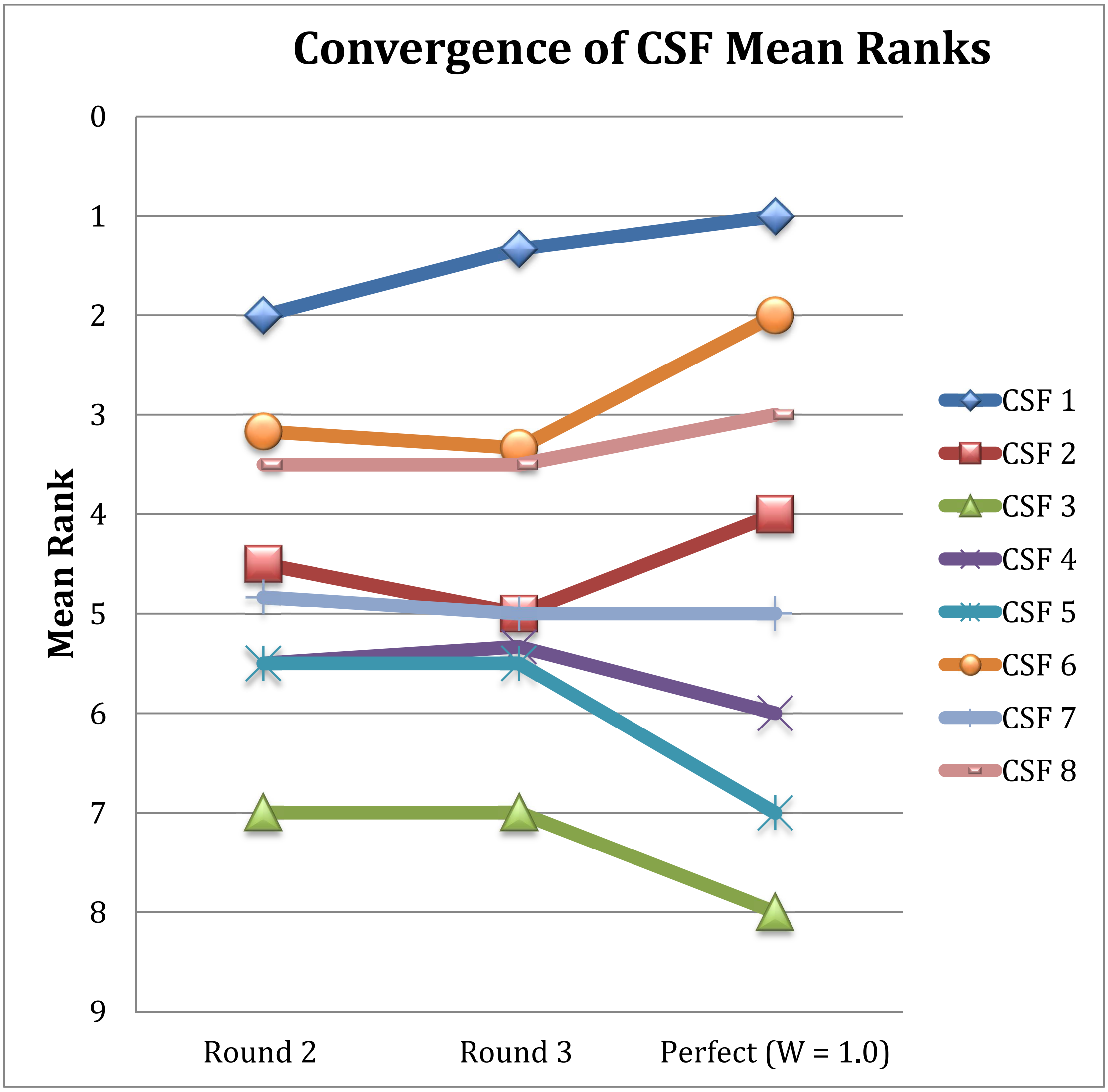

Figure 8 – Convergence of the Delphi study

The moderate level of convergence could be explained by the fact that the Delphi participants operate in different roles within their organisation. Principal consulting engineers – who by nature are more technically oriented – tend to give higher rankings to CSF's related to the nature and operation of the KMS itself. For instance, one participant, who is a Principal Engineer at a geotechnical engineering consultant, ranked CSF8 (quality of KMS) first. This particular participant is also a regular user and contributor to the KMS in his organisation. On the other hand, the participants who are directors and/or key decision makers at their respective firms agree on the primary importance of CSF1 (management support/buy-in).

The anomalies in some of the rankings could be caused by the experts making assumptions that may not be accurate. For instance, CSF6 (culture of knowledge sharing) was ranked 7 by one participant, despite having a low group mean ranking of 3.3. His explanation for this discrepancy was that “being a ‘professional’ practitioner infers [that] knowledge culture is ingrained”. In practice, this is not always true in some workplaces. The literature has identified many instances where knowledge sharing is inhibited due to the fear of sharing lessons learnt from mistakes and failures (Davenport et al, 1998; Wong, 2005). Competitive cultures that is harmful towards knowledge sharing often stem from the attitude that knowledge is power (Kulkarni et al, 2007; Liebowitz, 1999).

The level of personal involvement in KMS and other KM initiatives also affects the results. One participant, who has designed, promoted, and maintained a KMS in his firm ranked CSF4 (KM infrastructure) second, despite it having a group mean rank of 5.33. Being a heavily involved KMS user, this participant placed more emphasis on ownership of the system. This is also evident in his low ranking of CSF5 (Employee motivation and buy-in), which was assigned rank 8 (group mean rank = 5.33). His justification for this low ranking was that “incentive schemes [and] rewards do not provide ‘ownership’ of a KMS”. In contrast, the participants who have lesser degree of involvement with KMS tend to assign a higher ranking to CSF4 (KM infrastructure).

Further Delphi rounds could be carried out in order to improve the convergence of results ($W > 0.7$). However, this could prove to be unproductive as the experts may choose to stay with their rankings. Given that five out of six experts did not change their rankings in Round 3, this is a very likely outcome. The mean CSF rankings between Rounds 2 and 3 do not differ by much, which indicated that the point of minimal returns has been reached. Both Schmidt (1997) and Linstone & Turoff (2011) recommended that the Delphi rounds be terminated once this point has been reached. Schmidt (1997) also asserted that further rounds could artificially force the results towards the group mean ranking, which would then cast doubts over the validity of the data.

It must be noted that the objective of this research is not to determine the relative importance between the CSF's identified in the literature review. Insofar as the research is concerned, the research model and hypotheses need to be validated qualitatively, not quantitatively. The Delphi rounds have clearly identified the relevant CSF's for the implementation of KMS in the construction industry. In this sense, the moderate convergence of opinions achieved in Round 3 (W = 0.496) is acceptable. Further Delphi rounds would not add to the validity of the qualitative findings. On this basis, the researcher decided to terminate the Delphi phase.

3.3.4. DELPHI STUDY CONCLUSIONS

The final rankings of the CSF's are summarised in Table 8 below. The Delphi rankings are compared with the rankings from the literature review based on the number of research papers that identify the particular CSF (refer Table 3 for a summary of CSF's found in the literature). Note that the CSF rankings from the literature review encompass various industries outside the scope of this research, which is limited to the Australian construction industry.

Table 8 – Final Delphi ranking of CSFs for KMS

Number	Critical Success Factor	Delphi Final Rank	Rank from Literature Review
CSF 1	Management support	1	1
CSF 2	Develop a KM strategy	4	3
CSF 3	Performance metrics	8	5
CSF 4	Develop KM infrastructure	6	4
CSF 5	Employee motivation and buy-in	7	6
CSF 6	Culture of knowledge sharing	2	2
CSF 7	Availability of resources	5	7
CSF 8	Quality of KMS	3	8

There is generally good agreement between the findings of the Delphi and the literature review. Management support and culture of knowledge sharing (CSF No. 1 and No. 6 respectively) are highly regarded as critical success factors for KMS implementation, regardless of the industry where the firm operates. The greatest deviation from the literature is the relatively high importance given to CSF 8 (quality of KMS) by the Delphi participants compared to those found in the literature. One possible explanation is that researchers have assumed that the quality of the KMS is a given and therefore is not considered to be a CSF (Nevo & Chan, 2007). The Delphi participants have confirmed through their experience that this assumption is not appropriate, and that there are KMS in practice that are poorly developed, designed, and maintained. On this basis, the researcher proposes that CSF8 be included in the research model in addition to the other CSF's that have been validated through the Delphi process.

The validated research model now appears as below in Figure 9.

Figure 9 – Validated CSF research model

3.3.5. DELPHI STUDY LIMITATIONS

The contingency factors (size, type, and geographical spread of the firm) have not been investigated in detail in this research. There is a great variety in the sizes of the Delphi participants' firms, ranging from 35 staff members to well over 1000 staff. Some of them are locally based, whereas others have global presence with offices in the UK, Middle East, and Asia. As previously discussed, the research would have required a sample set of at least 18 people in order to adequately investigate the effects of the contingency factors on the CSF, which is beyond the scope of this research. Future studies into the contingency factors should involve a greater sample size as appropriate.

This Delphi study did not achieve the desired strong convergence of opinions ($W > 0.7$) after three rounds. It could be seen from Figure 8 that the mean ranking for most of the CSFs are only marginally apart. This was primarily because some experts retained their previous round 2 ranking in round 3. Given the small sample size, this had a significant effect on the group mean ranking and ultimately the end rankings. Whilst the experts were committed to the study, they were time poor, which could explain why some experts, having returned the questionnaire promptly, chose to retain their ranking without giving due consideration to the group results from the previous round. Future research should take into consideration the ability of the experts to dedicate time to completing the questionnaires in order to produce quality and accurate results.

Finally, whilst the Delphi experts' profiles are a valid representation of the Australian construction industry, it may not be representative of the same industry in other countries, particularly those in emerging markets.

4. KM GAP ANALYSIS

In the previous chapter we have validated the research model and hypotheses by consulting a panel of Delphi experts from the Australian construction industry. In this chapter, the findings of the Delphi process are applied in the context of the research sponsor, CVEng. This is achieved by conducting a gap analysis that compares CVEng's organizational profile against world's best KM practices as noted in the literature. The findings of the gap analysis are then used to make recommendations on how CVEng can improve its readiness to implement a KMS.

4.1. ORGANISATIONAL STUDY OF CVENG

The data collection for this research component was conducted internally within CVEng.

4.1.1. BRIEF OVERVIEW OF CVENG

CVEng is an Australian professional engineering consulting firm that specialises in building structures, civil works, and temporary construction works. With approximately 300 employees, and offices in London, Dubai, and most Australian capital cities, CVEng is capable of delivering engineering projects in development hotspots around the world. At its core business CVEng employs a team of engineers, draftspersons, and project managers to deliver projects and generate revenues. CVEng also employs teams of accountants, lawyers, IT support, human resource and marketing managers to support its core business.

CVEng was originally established in 1982 as a Brisbane-based small engineering consulting firm with only two employees. Within twenty Years CVEng rose to become the prominent engineering consulting firm in Queensland. In just over a decade, CVEng has grown to an international business, with approximately 300 employees in offices around Australia, the UK, and the Middle East.

4.1.2. DATA COLLECTION METHODOLOGY

Two methods for collecting the qualitative data required to assemble an organizational profile of CVEng were considered, namely company-wide survey and focused interviews. Both methods sought to identify CVEng's strengths and weaknesses in relation to the various critical success factors for KMS. The main difference between the two methods is the number of samples in the population set. It was originally envisaged that the survey will be sent out to all employees of CVEng, which could lead to a sample population set in excess of 100. The interviews, on the other hand, will focus on a small, specialized set of senior managers and/or directors in CVEng. The advantage of the survey method is the relatively large population sample set, which would ensure that a cross section of the company is fairly represented. However, the there is a palpable risk that the survey participation rates could be much lower than anticipated, which would reduce the reliability of the collected data. The quality of the survey data would depend largely on the willingness and motivation of the individual participation, which in a large sample set, would vary. Even if the company enforces participation to ensure a high survey return rate, the participants could still complete the survey for the sake of compliance, which could result in bad data. Further, due to the scale of the survey the data collection may take longer than planned.

The focused interviews would overcome most of the shortcomings of the group survey by limiting the sample set to a handful of individuals who are intimately involved in the running of the business, such as directors and senior executives. These individuals have an intrinsic interest in the findings of this research study. As such, they are more likely to provide a valuable and realistic assessment of CVEng's organizational strengths and weaknesses than the production staff. The small scale of the data collection would also be easier to manage and would not take as much time as the survey. Based on these reasons, the focused interview has been adopted to create an organizational profile of CVEng.

For the purposes of this study a sample set of 4 people was selected, which consists of four senior executives and directors of CVEng. All interviewees have at least 10 years experience working in CVEng. For reasons of confidentiality, the interviewees shall remain anonymous. The interviews were conducted on a one-on-one basis. At the start of the interview, the interviewees were briefed on the Delphi study results and the research model. Each CSF was then discussed in the context of CVEng. The interview findings are discussed in the following section.

4.2. CVENG ORGANISATIONAL PROFILE

In this section we examine CVEng's strengths and weaknesses in relation to the CSF's listed in the research model, as listed below in decreasing order of importance. Recommendations are then made with respect to each CSF following an assessment of the gap in organisational readiness in implementing a KMS.

1. Management Support
2. Culture
3. Quality
4. KM Strategy
5. Resources
6. KM Infrastructure
7. Employee Motivation
8. Performance Metrics

4.2.1. MANAGEMENT SUPPORT

The board of CVEng has instigated a number of innovation and KMS initiatives since the company was established in the 1980s. One example of a successful initiative is the database of key clients and contacts, which is an invaluable knowledge-sharing tool in the field of business development within CVEng. The database was originally created out of necessity to manage business contacts with key clients but was eventually recognised by the board as an essential KMS for business development activities. The CVEng board has been active in its support towards the maintenance and continual upkeep towards the client database. Key to this support has been the allocation of resources (time and financial) by the board to the few individuals in the business development department who own and maintain the KMS.

Another example of a successful KMS is the drafting standards library, which is a collection of standard CAD procedures and best-practice examples that is intended to ensure a consistent and high-quality product, i.e. engineering drawings and specifications. The drafting standards library is made available to every draftsperson in the company and is also accessible to engineers and project managers. As with the client database, success in this KMS can be attributed to strategic support that the CVEng board has been providing to the key drivers behind the initiative, in this instance the group drafting manager.

However, successful initiatives such as the client database and the drafting standards library are an exception rather than a rule. The following are examples of other KMS initiatives that did not achieve the same level of success as those described above:

- **Technical Design Manual.** Work on the design manual started approximately 15 years ago by junior staff members. The draft manual has not been completed and now contains out of date information that needs to be updated to reflect current design practices and materials. There appears to be an opinion held by some board members in the past that the design manual is a "grass-roots level KMS", implying that its creation was not deemed to be essential to the success of the business. This could explain why the design manual was never completed. However, there appears to be a consensus within the board that this design manual is now strategically required in order to ensure that the business remains competitive in current market conditions.

- **Engineering Technical Forums.** The company intranet houses a forum whereby staff members can share technical information in a public forum and leverage the knowledge of the company when solving challenging engineering problems. However, very few engineers contribute to or use the forum. The researcher found that the majority of staff, including the interviewees, does not visit the forum at all.
- **Design aid spread sheets.** Over the years various staff members have created various design aid spreadsheets. Some of these spread sheets have undergone an independent Quality Assurance check within the company and are now available to download and use from the company intranet. However, a few spreadsheets have been removed from the intranet due to bugs and errors in the computations. These spreadsheets have not been amended, which led to staff members creating their own spreadsheets – out of necessity – that have not been QA-checked by the company. In some cases crucial errors in computation have been identified in these ad hoc spreadsheets.
- **Innovation Incubator group.** The group was instigated in 2005 and consisted of people who own significant intellectual property in the company. The group used to meet regularly to share knowledge and to identify ways in which their intellectual property can be leveraged to benefit the organisation as a whole. The incubator group stopped in 2007 due to consistent lack of meaningful progress in any area, due to incubator members being expected to develop these works in their spare time.
- **Innovation Management Programme (IMP).** The IMP is a programme that was designed to create innovation champions in the company who are expected to drive innovation from grassroots level up. These champions are assigned a certain area of innovation (e.g. risk management, knowledge management, marketing, leadership)

and are to research their assigned topic as part of a post-graduate research degree funded by the company. Each champion is to be allocated a mentor and an incubator group – a group of people who assist the champion in the research and implementation of their assigned topic. The IMP was introduced in 2009. The first round of post-graduate research was due to finish by 2011, with the second round starting in the same year. However, out of the seven first round champions only four remain and they are due to finish the research in 2013. The Masters mentor system and incubator groups have ceased to exist.

The interviewees attributed the failure of the above initiatives to the following causes:

- CVEng is a boutique engineering consulting group. It is in essence a small organisation competing in a large market where its competitors are large, international, multi-disciplinary consulting firms. This affects the business model and scale of operations. The depth of relationship with clients, and the rewards and consequences it offers affect business strategy. Project revenue generation and client relationship management are considered to be more important than everything else.
- Innovation, KMS and its implementation are currently not part of KPIs in the performance of the Executive Directors, such as the CEO and CFO. No clear ownership and accountability exists with any of the above innovation initiatives.
- KM is actually part of the Global Operations Director's role, but commercial risk and company profit are considered to be more important. The Global Operations Director role is too big to care for both; hence KM has not been actively managed.

Recommendations

CVEng management needs to change their approach towards KMS in order for it to be a success. Instead of the KMS being a “nice to have” business initiative, it needs to be an integral part of the business vision and strategy. This shift in paradigm is the first crucial step towards KMS implementation as it activates the other CSFs. Both the literature and the Delphi panellists are unanimous in ranking management support as the top CSF for KMS implementation.

With this new paradigm, CVEng management then needs to demonstrate leadership by driving and supporting KMS initiatives from top level down. One way of achieving this would be to assign ownership of the KMS to an Executive Director or a Knowledge Manager and to establish KPIs for that role in relation to KMS implementation. This will be discussed in more detail in Section 4.2.6 (CSF – KM Infrastructure). Management’s support of the KMS would need to be communicated clearly to all staff members in order for the organisation to understand and accept this strategic shift in attitude (refer Section 4.2.4 for more detailed discussions on strategic communication).

4.2.2. CULTURE

The interviewees generally agree that CVEng has a good knowledge sharing culture, where staff members do not feel that they could be disadvantaged by sharing their knowledge with others (Kulkarni et al, 2007; Davenport et al, 1998; Wong, 2005). There is no evidence that knowledge hoarding or harmfully competitive behaviour is present in the organisation. A particular strength in the organisational culture is the openness by which management embraces new ideas or ways of solving engineering problems proposed by junior staff members. Davenport et al (1998) considered this to be a characteristic of a friendly knowledge-sharing culture. Unfortunately this openness has resulted in a lack of consistency in the approach to engineering design. This often creates disagreements between the design team and the independent QA check team, which leads to inefficiencies and delays in project delivery.

The organisational culture has not been actively endorsed or promoted by the board or the management. For example, in the Sydney office there have been a number of efforts in establishing regular in-house training sessions for the engineers in the past few years, but these ceased to continue after a few sessions. On the other hand, the London office has been running regular training sessions successfully over the last few years. There is a consensus amongst the interviewees that company culture needs to be driven from the top down in order to ensure consistency throughout the organisation. One interviewee remarked that the accountability for driving positive company culture needs to rest with the various offices, not necessarily with the board of management.

Knowledge sharing among CVEng staff members occurs frequently on a daily basis in the offices but are not formalised or structured in a way that enables it to be leveraged to benefit the company as a whole. Examples of this include the lack of in-house "lessons learnt" presentations on projects and the lack of participation in in-house technical forums by the engineers. The formalisation and promotion of this culture will require the support and leadership of the management, i.e. CSF No. 1 (Drucker, 1996).

Recommendations

CVEng management should attempt to define, formalise, and promote a knowledge-friendly organizational culture based on the business vision and values that are held in high regard in the firm. These discussions can take place during the regional or board strategy sessions held annually. A unified approach to cultivating this culture would ensure consistency across the organization. A well-defined corporate culture that promotes knowledge sharing and creation would act as a "corporate glue" that binds employees to the organizational objectives (Drucker, 1996 as quoted in Bishop et al, 2008).

The task of promoting the culture should be allocated to Principals and Associates who actively manage project teams. Cultural transformation in an organisation does not happen instantaneously, but the process needs to be initiated by the top management.

4.2.3. QUALITY OF KMS

All interviewees agree that the quality of the KMS is critical to its success. Quality of content and ease of access have been cited as the main key performance indicators of good KMS quality.

The CVEng intranet is an operational KMS that stores a substantial amount of company information that is relevant to the day-to-day running of the business. The information stored includes company policies and procedures, Quality Assurance procedures and work practices, engineering design aids, technical notes, Occupational Health & Safety guidelines and forms, among many others. Whilst the majority of files stored in the intranet are kept up to date, there is a substantial number of files that have been removed and not been replaced. It is often difficult to locate files in the intranet. There is no user-friendly search function that enables rapid locating of files. Having dedicated staff members whose task is to maintain and improve the intranet could easily rectify most of these issues. However, the costs associated with the maintenance and upkeep of the KMS have been identified by some interviewees as a possible obstacle to implementing it. This will be discussed in more detail in Section 4.2.5 CSF No. 5 – resources.

Recommendations

KMS ownership is essential in ensuring its successful design and implementation. To this end the role of Knowledge Manager should be created in CVEng to take ownership over the KMS (refer Section 4.2.6 for more discussions on this CSF – KM Infrastructure). A well-designed KMS will take sustained financial support and time to develop, but the long-term efficiencies that it will bring can justify the initial investment and capital costs.

The KMS needs to be designed to suit the needs and processes of CVEng. Staff input and feedback should be sought and incorporated into the design of the KMS in order to best address the needs of the organization. Discussions about what constitutes a well-designed KMS are not within the scope of this study. Interested readers are referred to another research conducted by a colleague of the author under the Innovation Management Programme, who is also an employee of CVEng.

The following KPIs should be considered in the design of the KMS:

- **Quality and breadth of content.** The KMS should address knowledge areas encompassing technical and non-technical know-how. The KMS design should ensure that the needs of all users in the organization, from graduate engineers, draftspersons to business executives and the regional managers are addressed. The design of the KMS should focus on the quality of content, not quantity in order to prevent it from becoming an "empty library" (Liebowitz, 1999). The contents should be regularly updated to ensure that the information is relevant to the current market conditions and technology.
- **Ease of use.** The KMS interface design should facilitate rapid location of information. A search engine should be employed to achieve this. The information in the KMS should be categorized and arranged in an intuitive, easy-to-follow manner. Links to the KMS could be placed in the CVEng intranet to ensure that everyone has access.

4.2.4. KM STRATEGY

CVEng conducts annual strategy sessions that involve key staff members from various offices. The participants include board members, state managers, business development executives, and principals and associates of the company. During these strategy sessions the participants would review the state of the company in the current market conditions and identify opportunities for growth and expansion. Organisational goals and objectives are set for the short, medium, and long terms and key performance indicators be established to monitor progress.

Strategic outcomes from the annual strategy sessions are usually communicated to staff members via company-wide communiqués, presentations at local offices by state managers, and 'state-of-the-nation' addresses by the Chairman. The company vision has often been quoted during these addresses and presentations. Whether this vision has been embraced, internalised, and adopted by all staff members remains uncertain. Strategy discussions rarely occur at other, more frequent instances such as project team meetings. A number of interviewees have acknowledged that the communication of organisational objectives and strategy towards CVEng staff members has been “poor”. They remarked that such communication usually focuses on short-term goals (less than 6 months) but does not address the long-term direction of the company. As a result there is a perception among staff members that they are not privy to the long-term company strategy and as such they are less likely to buy into it. However, this is in contrast to the opinion of one interviewee, who commented that he has received positive feedback from some staff members regarding the strategy communiqués. These opposing views indicate that the CVEng management has not sought enough feedback from staff members to ensure that organisational strategy has been successfully communicated.

In the context of KMS, the link between organisational goals and how the KMS can contribute to their success must be well communicated to the staff (Zack, 1999; Bishop et al, 2008; Liebowitz, 1999) in order to ensure the success of the KMS. To this end, the primary responsibility for ensuring that the KMS goals and objectives are communicated and are understood and accepted by staff members lies with CVEng management (Davenport et al, 1998).

The majority of engineering problems in current projects have been encountered and addressed before, similarly but never identically, as no engineering problems are the same, in past projects. Over time, CVEng has accumulated a wealth of Intellectual Property that mostly resides on engineering drawings and in people’s minds. CVEng, being a consulting engineering firm, relies heavily on its Intellectual Property well when solving current engineering problems. As such, the KM strategy for CVEng should be focused on the “codification” approach, supported by “personalization” approach (refer Section 2.5 - literature review for discussions on the different KM strategies). Examples of a KMS that supports a “codification” strategy include a Technical Design Manual, and a best-practice Drafting Standards Manual.

Recommendations

As outlined before in Section 4.2.1 (CSF1), the CVEng business strategy needs to incorporate the use of KMS to ensure its success. This strategy should be clearly communicated to all staff via presentations, company-wide communiqués, and Chairman's "state-of-the-nation" addresses as is currently done in CVEng. Management should seek feedback from an adequate sample of staff members to ensure that the strategy has been successfully communicated and internalized by all.

To further reinforce the communication of KM strategy by top management, Principals and Associates should be encouraged promote the KMS use in their projects and articulate how this relates to the overall business strategy. The promotion and utilization of KMS in projects could be set as KPIs when reviewing the performance of Principals and Associates.

4.2.5. RESOURCES

The interviewees are unanimous in assigning the lack of resources as the primary reason behind the many unsuccessful attempts towards innovation in CVEng, such as the technical design manuals and the in-house training sessions in the Sydney office. There are instances in CVEng where successful innovations have resulted due to the provision of resources (financial support, time, human resources) by management. For example, the on-line project commercial management database has been generally accepted as a successful innovation in CVEng. Its success has been attributed to the leadership of the CFO and the provision of dedicated staff members who created and maintain it.

At present any resources spent on KMS or innovation related activities are paid for by the various CVEng offices locally. There is no budget allocated for KMS on a group level. There exists a "financial disincentive" for the various CVEng offices to contribute towards KMS, since any resources spent on KMS won't generate project or branch revenues in the accounting books, which is the primary KPI of each branch in the company. And yet, as one interviewee pointed out, substantial gains in efficiency and profit could be gained by investing in KMS since "90% of the knowledge we sell is knowledge already known".

There is strong consensus among the interviewees that resource as a CSF is second only to management support in order of importance. This seems to correlate to the research findings of Wong (2005) who suggested that resources is an essential CSF that is specific to small and medium sized firms, which often operate on smaller, tighter budgets. Furthermore, Fong & Kwok (2009) reported that the availability of resources is the main obstacle for Hong Kong construction firms wanting to implement a KM initiative, due to the transient and intensive nature of construction projects, and the rate at which people move from one project to the next. Consequently, there is hardly any time for project teams to spend on KM activities. This would suggest that the lack of resources is a common problem across the construction industry.

The scarcity of resources for KM or innovation initiatives is attributed to the company's "unique" position in the market. With approximately 300 employees worldwide, CVEng is a relatively small organisation competing in a large market where its competitors are large multi-disciplinary engineering consulting companies. Due to its small size, CVEng has been able to maintain working relationships with clients who have direct communication access to the Chairman and other directors. Due to this transparency, there is greater personal involvement and accountability on the part of the directors to ensure that client's needs and project demands are being met above all else. Consequently, the resources required to foster innovation and drive a KMS are often diverted towards projects with little consideration towards the impacts this may have on the KMS.

Recommendations

Sufficient resources (time and funding) need to be allocated to the development and implementation of the KMS. Lack of resources has been singled out as one of the main reasons why previous innovation initiatives in CVEng have failed. Regional offices should not be penalized for spending resources on KMS related activities. To this end an allowance should be made in the group budget for the KMS. This alleviate the financial pressure on the local offices to meet target margins and revenues when investing in the KMS, hence allowing them to dedicate an agreed portion of their resources for KMS related activities.

4.2.6. DEVELOP KM INFRASTRUCTURE

There is a consensus among the interviewees on the importance of developing a KM infrastructure as a critical success factor. Central to this infrastructure is the establishment of the role of the knowledge manager or officer – a person whose role is to filter the knowledge that enters the KMS, and to maintain the quality and relevance of the KMS. Such manager would ensure ownership of the KMS, provided that the person selected is the right person for the role. Ideally, the knowledge manager is a technical person who is passionate about innovation and knowledge management. The manager would also act as a KMS champion who promotes the use of the KMS in the daily business activities of the company.

At present the role of the knowledge manager as described above does not exist in CVEng, although the office of the National Quality Manager in CVEng is a management role that deals with a key business success issue, in this case quality systems. The Quality Manager owns the quality assurance system in CVEng and ensures that all quality procedures, engineering specifications, drawings standards are kept up to date. There is a general consensus that CVEng's quality systems have markedly improved since the role was established in 2008, resulting in better quality deliverables and consistency in engineering output. In the same way, the establishment of a knowledge manager role would ensure that the KMS benefits the firm.

The interviewees hold varying opinions as to how the knowledge manager role should be staffed. Most agree that the knowledge manager should be a long term, technical role. The knowledge manager should have a strong engineering background with an innate understanding of mostly engineering know-how in the KMS. Most recommended that the knowledge manager be recruited internally within CVEng. One interviewee suggested that the role should be assigned to an engineer on a fixed short-term rotational basis, e.g. 1 year maximum.

However, one interviewee did not agree that the knowledge manager is a critical success factor for KMS in CVEng. He asserted that it would be very difficult to recruit an engineer as a knowledge manager as the role tends to divert their time and experience away from the consulting side of the business, effectively hindering their career progression. He argued that a more effective solution would be to encourage engineers to make small contributions to the KMS at a time. This way small, manageable goals towards the creation of the KMS may be set and monitored more easily. This approach would be suited to an incremental change in the organisation over a number of years, but would not be applicable if the desired change is to be implemented relatively quickly.

Recommendations

The role of Knowledge Manager should be created within CVEng as the primary owner of the KMS. This role needs to be defined in a way that augments the existing infrastructure in CVEng. Role responsibilities and KPIs should then be established in order to ensure accountability and effective performance monitoring.

The selection of staff for this role is crucial to its long-term performance and effectiveness. Ideally, the Knowledge Manager should be a Senior Engineer or Associate who is intimately familiar with the processes of delivering a project from start to end. The Knowledge Manager should be a person who is passionate about innovation and change management, and is happy to receive internal recognition for his/her achievements.

4.2.7. EMPLOYEE MOTIVATION AND BUY-IN

At present CVEng does not have strategies in place that foster employee commitment and motivation for KM. Remuneration rewards are mainly based on project performance, with no formalised systems for assessing innovation, creativity, or knowledge sharing. In order for KM to be a success, radical changes will have to be made to the existing rewards and remuneration system to include knowledge-related activities. Such radical changes are difficult to plan and execute quickly and this may prove to be an inhibitor to a successful KM/KMS implementation.

Whilst the interviewees consider that employee buy-in is a critical success factor for KMS implementation in CVEng, they all agreed that motivation is best achieved when employees realise the value of KMS in improving their productivity and work quality. This corresponds to what Malhotra & Galetta (2003) calls employee commitment by internalisation. This approach would tend to have longer-lasting results than rewards or social recognition. In order to achieve the commitment by internalisation, the KMS must be of good quality, and employees must be educated as to how the KMS can benefit them, and then experience it for themselves. One interviewee was open to the possibility of tying reward systems to the extent of which employees contribute or use the KMS. This would tend to enforce compliance but could enhance the effectiveness of the internalisation strategy.

The CVEng forum illustrates how the above internalisation has not been achieved in CVEng (refer section 4.2.1 for description of the forum). The forum is a knowledge-sharing tool that the literature has identified as one of the more successful KM tools (ref). Whilst the drafting team in CVEng has used the forum relatively successfully, the same could not be said about the engineering team. The interviewees attributed the failure of the forum to the following causes:

- The perception commonly held among engineers that asking for assistance reflects badly on one's skills and competence. The interviewee also asserted that this perception appears to be endemic within the engineering profession. Studies by Davenport et al (1999) appear to confirm that this is the case.
- Low quality content. The forum has no moderator that regulates and monitors the quality of its contents.
- Being a small organisation, staff members have direct access to the sources of knowledge. They tend to approach these sources direct, as opposed to using the forum to obtain information.

Recommendations

The employee buy-in strategy should be focused on convincing staff members that using the KMS will benefit them, thereby achieving internalisation of employee commitment. To this end, the first step should be to design a KMS that best suits the organisation's needs and user groups (refer Section 4.2.3 for CSF – quality). Once this is achieved, management should educate staff members on how the KMS can benefit them. This could be achieved by means of staff presentations and workshops. Feedback should be sought from staff members to gauge the quality and relevance of the KMS in their daily work activities.

To complement the internalisation strategy, reward schemes may be set up to recognise the extent of KMS contribution or usage by staff members. KPIs specifically relating to KMS should be set up for Associates, Principals, and the Knowledge Manager (see Sections 4.2.4 and 4.2.5 on CSF – KM strategy and resources).

4.2.8. PERFORMANCE METRICS

A simple system of logging the number of views on an article in the KMS could be used to monitor the KMS usage. CVEng currently employs a software logging system that measures the utilisation of software in the firm. A similar system could be set up easily to measure the KMS utilisation. The utilisation log could be linked to performance reviews by means of setting up KPIs and by rewarding staff members who demonstrate frequent usage of the KMS. This could help improve staff commitment to using the KMS, albeit via compliance rather than by internalisation.

Another important aspect of performance metrics is to get actual feedback from staff members regarding the quality and usefulness of the KMS. The feedback could then be used to improve the KMS. Follow up feedback should be sought regularly in order to facilitate continuous improvement of the KMS.

4.3. GAP STUDY RECOMMENDATIONS

Based on the results of the gap study in the preceding section, a list of recommendations has been prepared in order to close the capability gap. These recommendations are summarised in Table 9 below.

Table 9 – Recommendations for KMS CSFs in CVEng

CSF	Recommendations
Management support	• Paradigm shift required: KMS is an integral part of the business vision and strategy • Demonstrate leadership: KMS initiatives to be driven by the board • Allocate responsibility for KMS implementation to a Director, or appoint a Knowledge Manager, and establish KPIs
Culture	• Management to formalize and drive a good knowledge sharing culture • Consistent approach to culture on all offices
Quality of KMS	• Ownership of KMS is essential to ensure its high quality • Focus on quality of content, ease of use, and accessibility • Allocate resources and assign ownership accordingly to achieve a high quality KMS
Develop KM Strategy	• Incorporate KMS in the business strategy • Communicate strategy to staff • Principals and Associates to promote KMS use in line with overall KM and business strategy in their projects • Seek sufficient staff feedback to ensure that the strategy has been successfully communicated and internalised
Resources	• Group level funding for KMS activities • Allocate time and funding for staff to work on KMS
KM Infrastructure	• Define the roles and responsibilities of a Knowledge Manager, then establish KPIs • Appoint a Knowledge Manager and agree on how it should be staffed
Employee motivation	• Focus on KMS quality • Educate staff on the benefits of using KMS • Focus on internalization of employee commitment • Reward schemes for staff members who contribute to or use the KMS
Performance metrics	• Develop a simple log record of KMS utilization • Link log to performance review

5. CONCLUSION

This thesis presents a list of critical success factors for KMS implementation specific to firms operating in the Australian construction industry. The findings of the Delphi study validate the hypotheses in the research model by leveraging the experience and knowledge of construction industry experts. The Delphi study also confirmed the author's assertion that there are no CSFs for KMS implementation that are specific to the construction industry, being a knowledge-based industry, even though there are some notable changed priorities. In particular, the Delphi experts, CVEng interviewees, and Fong & Kwok (2009) have identified the availability of resources as an important CSF in SMEs in the construction industry. Quality of KMS has emerged as a CSF despite it not being part of the research model. Most researches have simply assumed that the KMS quality is unparalleled, which explains why quality has rarely been considered as a CSF, except for a study by Nevo & Chan (2007).

The *raison d'être* for this thesis is to find an answer to the following research question:

> *HOW DO WE ENSURE THE SUCCESS OF A KMS IMPLEMENTATION IN A KNOWLEDGE-BASED ENGINEERING FIRM?*

The knowledge-based engineering firm referred to in this thesis is CVEng, the sponsor organisation who funded this research. In order to adequately address this question, a study was carried out to determine CVEng's readiness to implement a KMS. This gap study identified strengths and weaknesses within CVEng's organisational fabric that need to be considered when designing and implementing a KMS that is tailored to suit its needs. Recommendations were made in Section 4 addressing each CSF that was identified in the literature and the Delphi study. The study found that there are a number of fundamental changes required within the organisation prior to implementing the KMS. These changes cover a broad range of aspects of the organisation such as strategy, culture, financial support, leadership and effective communication.

The list of recommendations pertaining to organisational changes required for KMS has a practical use for CVEng and other small to medium firms aspiring to implement a KMS. It is envisaged that these recommendations be presented to the CVEng board for due consideration in the board strategy session, hopefully paving the way for a wave of cultural and paradigm shift towards a more KM-friendly environment throughout the organisation. The recommendations of this study apply most pertinently to CVEng, but other similar organisations in the construction industry may find some of the points raised in the thesis relevant to their circumstances. Notwithstanding, the list of CSFs for KMS implementation is expected to be applicable to a wide range of stakeholders within the construction industry.

This research is not without its limitations. The concept of contingency factors, despite being part of the research model was eventually not considered during validation via Delphi. To properly investigate the effects of the contingency factors in the Delphi process would have required a much greater sample size, which is outside the scope of this research. More detailed studies should be carried out with greater sample size in order to accurately determine the relationships between the contingency factors and the CSFs.

The gap study only involved CVEng directors and senior managers. Whilst these interviewees know the inside workings of the firm best, they are naturally biased and as such the assessment of CVEng's company profile may have been skewed towards the perspective of the managers. This is particularly true considering how the gap study identified the management's lack of awareness of staff feedback as a weakness in CVEng. A company-wide survey of CVEng addressed to all staff members would have been beneficial to even out the bias of the senior managers interviewed. It is recommended that this survey be carried out in CVEng prior to implementing the KMS in order to more accurately establish the organisational profile of CVEng.

Whilst the CSF list is a robust reference point for all future KMS implementation in CVEng, its usefulness is limited by their relatively generic nature.

Further research could be carried out to establish and assign specific KPIs for each CSF. For instance, a relevant KPI for CSF Culture could be the number of training sessions that a Principal or Associate conducts in a year. The KPIs would allow the performance of the KMS and the success of its implementation to be regularly monitored and benchmarked. Performance measurement via KPIs would also entail getting feedback in a perpetual process of continuous improvement.

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APPENDIX A – ETHICS PARTICIPATION CONSENT FORMS

PARTICIPANT INFORMATION for QUT RESEARCH PROJECT

Critical Success Factors for the Implementation of a Knowledge Management System in a Knowledge Based Engineering Firm

Research Team Contacts	
Tony Amidharmo	Researcher
Phone	[details withheld]
Email	[details withheld]

Description

This project is being undertaken as part of Masters research project for Tony Amidharmo. The project is funded by CVEng [real name withheld in confidence] and is part of a wider research umbrella currently being undertaken in CVEng as part of CVEng's Innovation Management Programme. All the information and data obtained from the research will be treated with utmost confidentiality and anonymity. The funding body will not have access to the data obtained during the project.

The purpose of this project is to understand what makes the implementation of a knowledge management system in an engineering firm successful. There has been many research conducted in various industries to this end, but scarcely any in the engineering/construction industry. Further, many previous studies tend to be theoretical and too general to be useful for an aspiring innovating engineering firm.

This research is aimed to address the above knowledge gap by drawing on the experience and expertise of professionals in the Australian engineering industry. It is hoped that the collective knowledge of these professionals can produce a practical and achievable list of critical success factors for the implementation of a knowledge management system in an engineering firm.

Participation

Your participation in this project is voluntary. If you do agree to participate, you can withdraw from participation at any time during the project without comment or penalty. Your decision to participate will in no way impact upon your current or future relationship with QUT (for example your grades) or with CVEng.

Your participation will involve two or more rounds of questionnaires. The questionnaires will be distributed to the participants via emails. The researcher intends to employ the Delphi research method, whereby the results of one round of questionnaires will be be fed back to the participants in subsequent rounds. This way good data convergence is achieved.

It is expected that the questionnaire rounds will take 3-4 weeks to complete, including data analysis. The completion of one round of questionnaire is expected to take 20-30 minutes of your time.

Expected benefits

It is expected that this project will benefit you. The final findings of the questionnaires will be reported back to you at the conclusion of the research project.

Risks

There are no risks beyond normal day-to-day living associated with your participation in this project.

Confidentiality

All comments and responses are anonymous and will be treated confidentially. The names of individual persons are not required in any of the responses.

Consent to Participate

The return of the completed questionnaire is accepted as an indication of your consent to participate in this project. We would like to ask you to sign a written consent form (enclosed) to confirm your agreement to participate.

Questions / further information about the project

Please contact the researcher named above to have any questions answered or if you require further information about the project.

Concerns / complaints regarding the conduct of the project

QUT is committed to researcher integrity and the ethical conduct of research projects. However, if you do have any concerns or complaints about the ethical conduct of the project you may contact the QUT Research Ethics Coordinator on +61 7 3138 2091 or ethicscontact@qut.edu.au. The Research Ethics Coordinator is not connected with the research project and can facilitate a resolution to your concern in an impartial manner.

Statement of consent

By signing below, you are indicating that you:

- have read and understood the information document regarding this project
- have had any questions answered to your satisfaction
- understand that if you have any additional questions you can contact the research team
- understand that you are free to withdraw at any time, without comment or penalty
- understand that you can contact the Research Ethics Coordinator on +61 7 3138 2091 or ethicscontact@qut.edu.au if you have concerns about the ethical conduct of the project
- agree to participate in the project

Name ....

Signature ....

Date .... / .... / ....

APPENDIX B – DELPHI EMAIL INVITATION

Queensland University of Technology

Dear Mr. …,

RE: Invitation to Participate in a QUT Research Project

My name is Tony Amidharmo. I am a senior structural engineer from CVEng [real name withheld], and am currently studying for a Masters research degree in Engineering with Queensland University of Technology. I am writing to request your participation in my research project. My manager, (….) has suggested that your experience and expertise would be beneficial to this research.

The aim of my research is to identify the critical factors that will ensure the successful implementation of a knowledge management system (KMS) in firms operating in the construction industry. In light of increased competition and tougher market conditions, there is a real need for firms to leverage the "know-how" within the organisation in order to improve the quality of their products and services, and the efficiency of their delivery. The findings of this research are expected to benefit all firms aspiring to implement a successful KMS that facilitates innovation and structured knowledge sharing.

Your participation would involve completing three rounds of questionnaires, which will be conducted anonymously and confidentially. It is expected that this research will benefit you. By participating in this research, you will help generate new knowledge about KMS that will have practical applications in the industry. Further, the results of all the questionnaires will be reported back to you after each round. This way you will gain a unique insight into what other industry leaders (ie. your fellow participants) think and know about KMS.

Please refer to the attached participant information and consent forms for more details on the research project and how you can participate.

If you agree to participate in this research, please sign the attached consent form for QUT research and return it to me by mail or email (contact details below).

I look forward to your agreement to participate in this research. Please do not hesitate to contact me should you have any questions.

Kind regards,

Tony Amidharmo
Address: [details withheld]
Phone: [details withheld]
Email: [details withheld]

APPENDIX C – DELPHI QUESTIONNAIRE TEMPLATES

DELPHI QUESTIONNAIRE

Research topic: Critical success factors for the implementation of a knowledge management system in a knowledge-based firm in the construction industry

Researcher: Tony Amidharmo

Preamble

Knowledge Management System (KMS) is an information-based system that facilitates and enhances the organisational processes of knowledge creation, transfer, storage, retrieval, and application. Some examples of KMS include knowledge databases, intranet, technical notes, and on-line discussion forums.

Over the past few decades, attempts to implement a KMS on an organisational level have been met with varying levels of success. Many researchers and practicioners alike have conducted studies to identify the critical success factors (CSF) for the implementation of a KMS. However, studies that are specific to the construction industry are scarce in number. Further, most of these studies are theoretical in nature and their findings have not been validated by research data.

In this research, the Delphi method will be used to generate a list of CSF for the implementation of a KMS. The research data – i.e. opinions from experts in the construction industry – will be collected by means of several rounds of questionnaires, which generates a series of qualitative and quantitative data for analysis. The analysis findings will then determine the form and content of subsequent questionnaires, and so on until the group opinion is formed and is stable.

The Delphi method will be conducted in three rounds, as outlined below.

ROUND 1: Brainstorming of CSF

ROUND 2: Ranking of CSF

ROUND 3: Refinement of CSF list

Participating in this Study

You have been selected as a member of the Delphi expert panel. Over the next few weeks, you will be asked to complete three rounds of questionnaires. At the end of this period, the results of the questionnaires will be made available to you as a token of gratitude for your contribution.

Your participation is on a voluntary basis. Below are the conditions of voluntary participation:

- Confidentiality.
- Anonymity.
- Not asked to divulge any business-sensitive information.

The 2-page questionnaire can be found overleaf. The questionnaire should take no more than 30 minutes to complete.

Kindly return the completed questionnaire within 7 days of receiving the questionnaire. Many thanks in advance for your time and contribution. If you have any questions about the research, please do not hesitate to contact the undersigned.

Kind regards,

Tony Amidharmo
Mobile: [details withheld]
Email: [details withheld]

ROUND 1 – BRAINSTORMING OF CSFs

Firm:____

Number of employees:______________________________

Occupation:____________________________________

Your age (please circle):

20-30 31-40 41-50 51-60 60+

Please describe your involvement with knowledge management and KMS (tick as many boxes below as appropriate).

☐ I promote KM initiatives in my organisation

☐ I am a regular user of a KMS

☐ I am a regular contributor to a KMS

☐ I maintain the operation of a KMS

☐ I designed a KMS

☐ Other (please describe)______________________________

____

____

____

____

How many years have you been involved with KM? (please circle)

None 1-5 6-10 10+

Does your firm have a KMS currently in operation? (please circle)

YES NO

If yes, please describe the KMS (tick as many boxes below as appropriate).

☐ Knowledge database/repository

☐ Company intranet

☐ Online discussion forum

☐ Expert mapping or directory

☐ Groupware or collaborative software

☐ Other (please describe)____

____

____

____

If no, please indicate if there is a plan to implement a KM initiative in the next fiscal year. What will this involve? (50 words or less)

____

____

____

____

____

____

Please list at least 5 critical success factors for the implementation of a KMS. In other words, what are the most essential things that, if satisfactorily achieved, will result in a successful implementation of a KMS?

CSF1:____

____

CSF2:____

____

CSF3:____

____

CSF4:____

____

CSF5:____

____

Others:____

____

____

____

____

____

____

Please rank the above CSF’s in the order of decreasing importance (1 – most essential, 6 – least essential).

Critical Success Factor	**Rank (1 – 6)**
CSF 1	
CSF 2	
CSF 3	
CSF 4	
CSF 5	
Others	

Thank you for completing the Round 1 Delphi questionnaire.

Please return the completed questionnaire to the following address.

[details withheld]

att. Tony Amidharmo

or by scan/email:

[details withheld]

DELPHI QUESTIONNAIRE – ROUND 2

Research topic: Critical success factors for the implementation of a knowledge management system in a knowledge-based firm in the construction industry

<u>Researcher: Tony Amidharmo</u>

Preamble

Thank you for completing your Round 1 Delphi questionnaire. I received a 100% response rate from all seven participants, which is excellent. Please find below some charts describing the demography and profile of the Delphi participants.

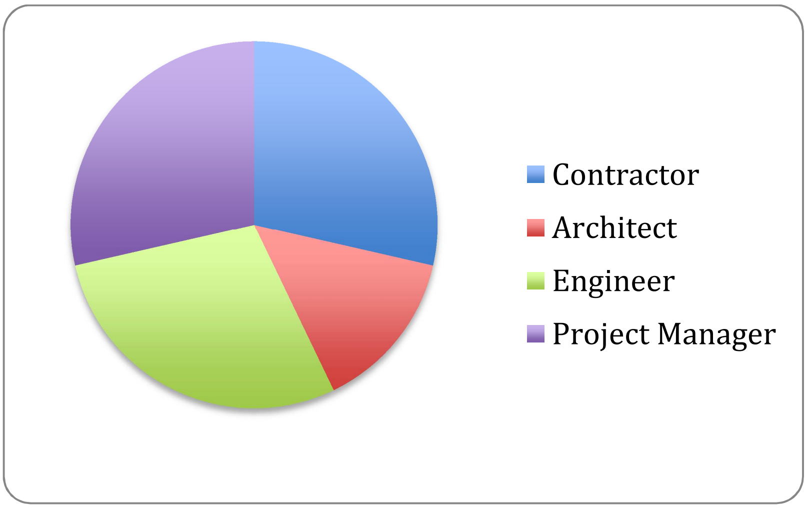

Figure 1 – Occupation of Delphi Participants

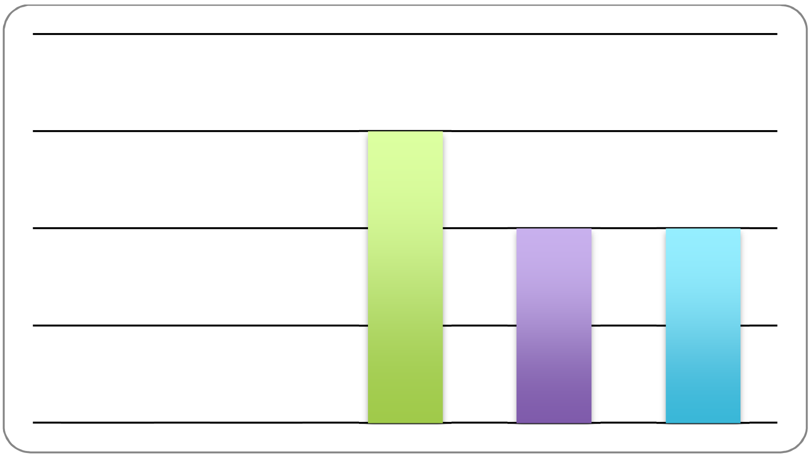

Figure 2 – Age of Delphi Participants

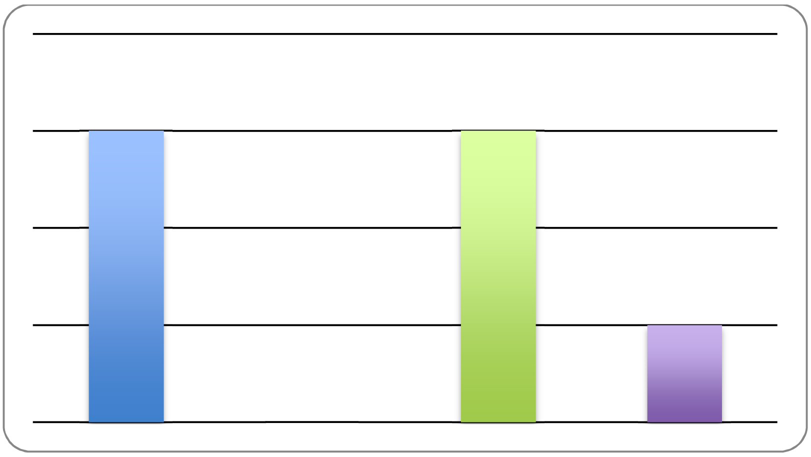

Figure 3 – Number of employees in the Delphi participant’s firm

In Round 2 Delphi we will review the results of Round 1 Delphi and attempt to rank the critical success factors (CSFs) in order of importance. The rankings will then be analysed statistically to measure the level of consensus between all Delphi participants.

Kindly return the completed questionnaire within 7 days of receiving the questionnaire. Many thanks in advance for your time and contribution. If you have any questions about the research, please do not hesitate to contact the undersigned.

Kind regards,

Tony Amidharmo
Mobile: [details withheld]
Email: [details withheld]

Round 1 Delphi Results

In Round 1 Delphi, the participants identified a number of common Critical Success Factors (CSF's) for KMS implementation. These CSF's correlate well with existing literature and research and are listed below.

Number	Critical Success Factor	Description
CSF 1	Management support	• Driven top-down by senior executives. • Implemented by middle managers. • Financial support is key.
CSF 2	Develop a Knowledge Management strategy	• Align KM strategy to the business model and existing systems and processes (e.g. QMS). • Communicate strategy to all staff.
CSF 3	Performance metrics	• Establish KPI's to monitor progress and facilitate continuous improvement.
CSF 4	Develop Knowledge Management infrastructure	• Ownership of KMS. • Creation of dedicated roles to filter, update, and maintain the KMS. • KMS training regimes.
CSF 5	Employee motivation and buy-in	• Incentive schemes that reward employees who use/contribute to the KMS. • All staff to use KMS. • Integrate KMS use with performance and salary reviews.
CSF 6	Culture of knowledge sharing	• All staff to be continually informed of new knowledge, e.g. Monthly knowledge sharing sessions. • Celebrate success and learn from failures. • Collaborative culture, not competitive.
CSF 7	Availability of resources	• Financial resource • Time allocation for KMS-related activities
CSF 8	Quality of KMS	• Easy to use • Reliable • Regularly updated to reflect current knowledge • Adequate cross-referencing of information.

ROUND 2 – RANKING OF CSF's

Please carefully rank the CSF's listed in the previous page in order of importance (1 – most essential, 8 – least essential).

Critical Success Factor	Rank (1 – 8)
CSF 1	
CSF 2	
CSF 3	
CSF 4	
CSF 5	
CSF 6	
CSF 7	
CSF 8	

Thank you for completing the Round 2 Delphi questionnaire.

Please return the completed questionnaire to the following address.

[details withheld]

att. Tony Amidharmo

or by scan/email:

[details withheld]

DELPHI QUESTIONNAIRE – ROUND 3

Research topic: Critical success factors for the implementation of a knowledge management system in a knowledge-based firm in the construction industry

Researcher: Tony Amidharmo

Introduction

Thank you for completing your Round 2 Delphi questionnaire. Six out of the seven Delphi panel members returned the questionnaire prior to Christmas. I have decided to proceed with the next questionnaire round with the reduced sample size in order to avoid further delays to the research progress.

In the previous questionnaire, you ranked the Critical Success Factors (CSF's) in order of importance. In this round, we will compare your rankings with those of the Delphi group's and examine the level of consensus within the group. You will then be asked to re-rank the CSF's, giving careful consideration to the opinions of others in the group.

Kindly complete and return the completed questionnaire within 7 days of receipt. Many thanks in advance for your time and contribution. If you have any questions about the research, please do not hesitate to contact the undersigned.

Kind regards,

Tony Amidharmo
Mobile: [details withheld]
Email: [details withheld]

Round 2 Delphi Results

The table below shows your ranking of the CSF in relation to the Delphi group's mean rank. The sample set consists of 6 respondents. There was weak-to-moderate agreement among the group members on the relative ranking of the CSF's in the previous round (Kendall's W = 0.414).

Table 1 – Summary of Round 2 Delphi Results

Number	Critical Success Factor[1]	Your ranking[2]	Group mean ranking[2]	% of respondents who gave the CSF a ranking ≤ 4
CSF 1	Management support	**1**	2.00	83%
CSF 2	Develop a Knowledge Management strategy	**7**	4.50	33%
CSF 3	Performance metrics	**8**	7.00	17%
CSF 4	Develop Knowledge Management infrastructure	**5**	5.50	17%
CSF 5	Employee motivation and buy-in	**3**	5.50	33%
CSF 6	Culture of knowledge sharing	**2**	3.17	83%
CSF 7	Availability of resources	**4**	4.83	50%
CSF 8	Quality of KMS	**6**	3.50	83%

Notes

[1] Refer Appendix (page 4) for a brief description of each CSF.

[2] Ranking in order of importance: 1 – most essential, 8 – least essential.

ROUND 3 – RE-RANKING OF CSF's

Please carefully review your CSF rankings with respect to the group's rankings as shown on Table 1. Where your rankings substantially differ from the group mean ranking, provide an explanation why below.

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After considering the group rankings in Table 1, please re-rank the CSF's listed in the previous page in order of importance (1 – most essential, 8 – least essential). You may choose to adopt the same rankings as before.

Critical Success Factor	Rank (1 – 8)
CSF 1	
CSF 2	
CSF 3	
CSF 4	
CSF 5	
CSF 6	
CSF 7	
CSF 8	

Thank you for completing the Round 3 Delphi questionnaire.

Please scan and email the completed questionnaire to the following email address.

[details withheld]

APPENDIX – BRIEF DESCRIPTION OF CSF'S

Number	Critical Success Factor	Description
CSF 1	Management support	• Driven top-down by senior executives. • Implemented by middle managers. • Financial support is key.
CSF 2	Develop a Knowledge Management strategy	• Align KM strategy to the business model and existing systems and processes (e.g. QMS). • Communicate strategy to all staff.
CSF 3	Performance metrics	• Establish KPI's to monitor progress and facilitate continuous improvement.
CSF 4	Develop Knowledge Management infrastructure	• Ownership of KMS. • Creation of dedicated roles to filter, update, and maintain the KMS. • KMS training regimes.
CSF 5	Employee motivation and buy-in	• Incentive schemes that reward employees who use/contribute to the KMS. • All staff to use KMS. • Integrate KMS use with performance and salary reviews.
CSF 6	Culture of knowledge sharing	• All staff to be continually informed of new knowledge, e.g. Monthly knowledge sharing sessions. • Celebrate success and learn from failures. • Collaborative culture, not competitive.
CSF 7	Availability of resources	• Financial resource • Time allocation for KMS-related activities
CSF 8	Quality of KMS	• Easy to use • Reliable • Regularly updated to reflect current knowledge • Adequate cross-referencing of information.